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Guide to Oil Waste Management Alternatives for
Used Oil, Oily Wastewater, Oily Sludge, and
Other Wastes Resulting from the Use of Oil Products

Energy and Environmental Research Corp., Irvine, CA

Prepared for:

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GUIDE TO OIL WASTE MANAGEMENT ALTERNATIVES
FOR USED OIL, OILY WASTEWATER, OILY SLUDGE, AND
OTHER WASTES RESULTING FROM THE USE OF OIL PRODUCTS

FINAL REPORT

Prepared for:

Alternative Technology Section
Toxic Substances Control Division
California Department of Health Services

in cooperation with
The United States Environmental Protection Agency

Prepared by:

Energy and Environmental Research Corporation
and its subcontractors:
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Evergreen Oil, Inc.

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This report presents the results of a study of oil waste management alternatives conducted for the California Department of Health Services in cooperation with the United States Environmental Protection Agency. The study includes regulations, established and emerging technologies, current practices, economics, and environmental impacts of oil waste management. The report focuses on methods of improving oil waste recyclability and phasing out land disposal. The report includes recommendations for industrial oil waste generators.

The study was performed by Energy and Environmental Research Corporation, with subcontracting by Robert H. Salvesen Associates and Evergreen Oil, Inc.

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DISCLAIMER

The statements and conclusions of this report are those of the Contractor and are not necessarily those of the State of California. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

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CHAPTER 1

SUMMARY AND CONCLUSIONS

The California Department of Health Services (DHS) has a broad hazardous waste reduction program to promote alternative technology and phase out land disposal. DHS contracted Energy and Environmental Research Corp. and its subcontractors, Robert H. Salvesen Associates and Evergreen Oil, Inc., to conduct this study of oil waste management alternatives. The objective is a study that can encourage and assist industries in California with improving their oil waste management. The results of the study are this report and two symposia conducted in April, 1988. Symposia proceedings have also been published. This report describes current regulation, generation, and management of oil waste in California. Recommendations are given for implementing successful used oil management programs.

1.1 Focus of Study

The study focuses on management alternatives that can be implemented by industry to minimize oil waste generation and increase oil waste recyclability. This study identifies alternatives that can be used to minimize oil waste generation and increase oil waste recycling. The study is limited to oil wastes resulting from oil usage. These wastes include used lubricants, coolants, cutting and machining oils, hydraulic fluids, oily wastewater and oily sludge. The study does not include polychlorinated biphenyl (PCB) oils or oils resulting from petroleum refining, production of oil products or petrochemical manufacturing.

It is important to characterize and understand the status of used oil management in California. This is because used oil can be either a valuable commodity if recycled or an environmental hazard if managed improperly. Used oil is generated in extremely large quantities. Over 100 million gallons are generated yearly in California. Used oil is regulated as a hazardous waste in California. It can contain hazardous substances such as heavy metals and toxic organic compounds. With land disposal capacity severely limited in California, alternative used oil management techniques must be explored. Used oil is also a recyclable waste, with potential for ultimate use as rerefined lube oil or fuel oil. This study is designed to assist used oil generators in selecting economical, environmentally sound management alternatives.

One source of information for this study was a literature search. This consisted of searching California government and university libraries, conducting remote computer searches of worldwide technical databases, and searching government publication abstracts. Another information source was interviews of used oil regulators, generators, collectors, transporters, recyclers, and rerefiners throughout California. These two sources revealed theoretical developments and current practices of used oil management.

This study characterizes:

- Used oil generation in California
- Existing and emerging used oil treatment technologies

- Economic and environmental impacts of oil waste management practices

1.2 Oil Waste Management

Oil waste is generated by a wide variety of industrial processes. Generators, regulators and recyclers all have different goals and needs. Onsite and offsite treatment techniques can both be viable depending on used oil composition and generation rate. Major findings of the study are summarized below.

Generator and Recycler Considerations

The primary needs of generators are to be made aware of the laws and management options available to them. Many generators are unaware that used oil is a hazardous waste for which they have legal liability, and that used oil is recyclable. Publicity and advertising programs by recyclers and government agencies can effectively educate generators. The needs of recyclers are to have workable, enforceable legislation and viable recycling economics.

The oil waste industry is composed of companies and individuals who generate, transport, process/treat/recycle, and market oil waste. Oil waste management begins with generation. It flows through the transportation industry into the recycling industry, where used oil is prepared for reuse or disposal.

The Used Oil Waste Stream

The two main categories of lubricating and process oils are automotive and industrial oils. Automotive oils include:

- Engine crankcase oils
- Transmission fluids, including power steering fluids
- Diesel engine oils
- Automotive hydraulic brake fluids

Industrial oils can be classified according to:

- General industrial:
 - Hydraulic
 - Compressor
 - Turbine
 - Bearing
 - Gear
 - Refrigeration
- Metalworking
- Process
- Railroad diesel
- Marine
- Natural gas engine
- Grease

Oily Waste

Oily waste includes bilge and ballast, rain runoff, washings from cleaning vehicles, and cutting oils. These materials are primarily water, containing from 0.1 to 5 percent oil. Oily waste recycling and purification processes include:

- 1) Time settling
- 2) Filtration
- 3) Ultrafiltration and reverse osmosis,
- 4) Magnetic separation
- 5) Centrifugation
- 6) Hydroclone separation
- 7) Distillation
- 8) Aeration
- 9) Pasteurization
- 10) Chemical treatment
- 11) Biological treatment
- 12) Carbon adsorption
- 13) Coalescing

For companies that generate more than 200 gallons per day of oily waste, it is usually economical to operate water removal plants. If less than 200 gallons per day is generated, it is more economical to utilize an offsite waste management service.

Many efficient, compact oily waste separators have recently become available. Devices differ mainly in initial cost, chemical usage and sludge generation.

Superfund oily wastes present special problems because they present immediate hazards to the environment. The three types of waste regulated under Superfund are spills and accidental releases, leaky storage tanks, and abandoned storage facilities. Incineration, oxidation techniques, and chemical treatment have been used successfully to treat Superfund oily wastes.

Regulations

California used oil laws can be summarized as follows:

- Used oil is classified as a hazardous waste in California. If it can be shown that the oil meets established specifications, covering mainly metals, halogens, PCBs, and flash point, then the oil is considered recycled or exempt oil and can be managed as a nonhazardous waste. Recycled and exempt oils can be used for fuel or other purposes.
- Used oil transporters must register with the California Department of Health Services as hazardous waste transporters.
- Blending used oils with virgin oils to meet specifications is prohibited.

Used oil is not a listed RCRA hazardous waste by the U.S. Environmental Protection Agency (EPA) (50 FR 41900). However, used oil not burned for energy recovery (e.g., disposal), and exhibiting a hazardous characteristic (e.g., EP toxic-Pb, or ignitable) would be a RCRA hazardous waste. EPA has debated such a listing, but studies have indicated that classifying used oil as a hazardous waste could cause an additional 60 to 130 million gallons per year to be disposed of by uncontrolled methods.

Used oil combustion for energy recovery is regulated by EPA under waste-as-fuel rules (40 CFR Part 266 Subpart E). These rules restrict the burning of off-specification used oils, which are oils that do not meet EPA's contaminant criteria, to certain devices such as industrial furnaces, industrial boilers, and utility boilers.

Onsite Management

Source reduction is the most effective way to reduce or eliminate used oil disposal problems. Use of water soluble oils, substitution of oils, extending oil life, reformulation, use of biodegradable oils, and employee training programs are effective methods of source reduction. Source reduction employee training programs should include:

- 1) Problem definition
- 2) Reasons for changes
- 3) Description of desired practices
- 4) Specifics of new practices
- 5) Management support
- 6) Incentives for change
- 7) Follow-up to assure acceptance

The most important aspect of contaminant control is to prevent cross-contamination of incompatible streams. This involves careful segregation of used oil streams to prevent introduction of heavy metals, solvents, halogenated organics, or radioactivity into recyclable streams. Knowledge of composition of each waste stream, properly labeled collection drums, and personnel training programs are effective ways of minimizing contaminants in used oils.

Guidelines for mixing of used oils are a function of the types of oils available and the desired recycle or disposal options. Recycling for the original purpose requires strict segregation. For fuel usage or blending into asphalt, all oils can be mixed together except those containing halogens or having flash point below 130 °F. Residual fuel specifications generally allow from 1-2 percent water and sediment.

Collection for Offsite Management

Over 50 million gallons of used oil is collected in California each year. Used oil collection programs accumulate used oil from individuals for the purpose of recycling or disposing of it. Programs may be operated by either government or industrial groups and can be either public services or commercial ventures. Need for disposal, economics, and convenience are the primary generator considerations in selecting a collection program. The most common types of used oil collection programs are as follows:

- Collection stations accept used oil brought in by generators. They generally charge from 25 cents to one dollar per gallon to offset their own costs.
- Transporters collect used oil from collection stations and industrial sources. They generally charge from 15 to 25 cents per gallon to transport used oils.
- Public collection programs accept oil brought in by the public at no charge.

1.3 Technology

Used oil recycling and rerefining methods have existed for decades. However, stricter regulations and declining land disposal capacity have created a need for processes that produce little or no waste by-products and can effectively deal with hazardous contaminants. Major technological findings are summarized below.

Reuse

The most economically attractive means of reuse for used oils is downgrading for fuel use. About 80 percent of all used oils recycled in California (or 42 million gallons per year) are utilized as fuel. Most of this oil is blended into bunker fuel for use on ships. Recycling to produce lube oils or industrial oils is another major method of used oil reuse. Generally, this involves contaminant removal and physical processing. Used oils are commonly added to asphalt to serve as plasticizers and extenders. This is beneficial to the asphalt and it encapsulates the hazardous materials found in the used oil. Residues from some rerefining methods can also be added to asphalt.

Rerefining

Much rerefining research was done in the 1970s and early 1980s when oil prices were high. Interest in rerefining has declined in recent years. Currently, there are only five operational rerefiners in California. Increasing environmental concerns are increasing recycling costs. This is driving small recyclers and rerefiners out of business and favoring large operators. Traditional acid-clay rerefining methods have decreased in popularity recently because they produce acid sludge requiring disposal.

The general approach to rerefining is to:

- 1) Remove water
- 2) Remove additives and sludge
- 3) Remove low boiling hydrocarbons and solvents
- 4) Remove impurities
- 5) Fractionate
- 6) Perform final finishing

Specific rerefining technologies can be described as follows:

- KTI process uses vacuum distillation for recovery of lube fraction and rejection of residue. The process then uses hydrogenation for finishing. The final products are lube oil that is of quality at least as high as virgin lube oil, and asphalt bottoms. No waste is generated.
- Krupp process uses supercritical extraction with propane or other light gases for fractionation and sludge precipitation. Clay treatment is used. A waste sludge is generated.
- Recyclon process uses sodium treating followed by distillation overhead of the low boiling reaction products. The process then uses short path distillation to recover oil and reject residue.
- IFP process uses a membrane pretreating process that dilutes oil with light naphtha and uses ultrafiltration to remove impurities. The process then uses minimal sulfuric acid treating and subcritical propane precipitation.
- PROP process uses precipitation with aqueous ammonium sulfate at elevated temperature and pressure, followed by separation of the solid reaction products from the oil. The process then uses hydrogenation for finishing.
- Snamprogetti process uses paraffin extraction to remove metals, sludge, and additives, and then uses hydrotreating for finishing.
- BERC process uses a mixture of oxygenated solvents to reduce coking and fouling precursors. The process then uses vacuum distillation to recover the lube fraction and hydrotreating for final finishing.
- Matthys process: Uses minimal amounts of sulfuric acid treatment and clay contacting.
- Dieselclene process: Coagulates contaminants and removes them as insoluble matter, leaving unused portions of the chemicals added.
- RTI process: Uses cyclonic vacuum distillation and clay treating for production of lube oils.

Combustion

Used oil combustion can be performed either for disposal or to recover energy. Combustion destroys organic compounds and concentrates remaining hazardous compounds in the ash.

Uncontrolled incineration, or flaring, is simple but inefficient. Flaring is so tightly regulated that it is essentially eliminated as an option in California. Liquid injection incinerators and rotary kilns are the most commonly used devices for used oil incineration. Incineration is a

relatively expensive process and is infrequently used. Less than 2 percent of used oil in California is burned without energy recovery.

Over 80 percent of reprocessed used oil is used as fuel in California. Devices commonly used include ship engines, kilns, furnaces, external combustion boilers, internal combustion engines and clay dryers. Combustion for energy recovery is economically favorable, because it both disposes of oils and replaces fuel that would otherwise have to be purchased.

Unit Operations

Mechanical separation devices are characterized by their simplicity and low capital costs. The most commonly used methods of solids removal are:

- Gravity settling
- Filtration
- Magnetic separation
- Centrifugation
- Hydroclones
- Flotation

For emulsion breaking and water removal, the most commonly used unit operations are:

- Gravity settling
- Centrifugation
- Hydroclones
- Membrane processes
- Vacuum distillation
- Adsorption
- Coalescing plate filters
- Extraction
- Chemical treatment
- Skimming
- Biological treatment

Atmospheric distillation and vacuum distillation are generally used for light ends removal.

For removal of sludge, metals and tar, the methods generally used are:

- Extraction/deasphalting
- Vacuum distillation
- Clay treating
- Sodium treating
- Chemical precipitation
- Centrifugation with triethylamine

Final finishing is usually done using hydrotreating or clay treating.

Biological Treatment

Biological methods use microorganisms to destroy the organic material in oil waste. Some of the organic material, the inorganic contaminants, and dead

microorganisms are concentrated in a sludge which must be managed. Biological methods require low oil concentrations and thus are usually used on oily wastewater.

The most commonly used biological treatment techniques are:

- Trickling filters
- Activated sludge
- Anaerobic digestion
- Rotating contactors
- Bioaugmentation

Biological methods are inexpensive to operate. However, they are relatively slow, produce large quantities of sludge, and are inefficient at destroying PCBs, phenols, chlorinated branched hydrocarbons and some other types of organic materials.

Wastewater Pretreatment

Industrial oily wastewater contains small amounts of free, emulsified, or dissolved oil, and contaminants such as dirt, metals, and organic compounds. Excessive contaminant levels necessitate pretreatment prior to sewer discharge. One category of wastewater contaminants is toxic pollutants, which harm sewer bacteria and reduce efficiency. The second category of contaminants is high-strength pollutants, which can be handled but place increased burden on the sewer system due to their high concentration. Oil waste is considered a high-strength pollutant.

Excess oil in sewer systems can cause:

- Inhibition of biological processes
- Clogging of screens
- Interference with skimming
- Fouling of float systems and electrodes
- Fire and explosion hazards

Pretreatment provides neutralization, oil removal, treatment of toxic materials, and solids removal. Oil removal processes include:

- Gravitational separation
- Chemical emulsion breaking
- Air flotation
- Carbon adsorption
- Biological treatment

Emerging Technologies

Four promising emerging technologies for used oil treatment are supercritical water oxidation, the Zimpro process, the B.E.S.T. process, and use of centralized waste treatment facilities. These technologies can be described as follows:

- Supercritical water oxidation uses properties of water above its critical point to oxidize organics, convert inorganic materials to

salts, and liberate energy. High efficiency has been achieved during field demonstrations. The process is now being applied commercially.

- The Zimpro wet oxidation process involves thermal oxidation of organics and inorganics in the aqueous phase under subcritical conditions. The process has been applied worldwide to municipal sludge and has recently been used for hazardous waste disposal.
- The B.E.S.T. process uses centrifugation with triethylamine to separate oils, water, and solids. It has been successfully used to clean up contaminated oil sludges.
- DuPont has a centralized waste treatment facility in New Jersey that accepts contaminated oily wastewater from outside sources. This utilizes the excess capacity of DuPont's chemical treatment complex.

1.4 Extended Perspectives

Regulation and management of used oils in California have evolved rapidly in recent years. This is due to increasing environmental concerns. Other states and countries have also displayed innovative trends in used oil management and legislation.

Impacts and Trends

Land disposal has been virtually eliminated as a used oil management option. This is due to its diminished capacity and increased regulation. Recycling techniques that generate waste by-products, such as the acid-clay process, are being replaced by processes that generate no waste, such as the KTI process.

Waste minimization can reduce treatment and disposal costs, and can reduce reliance on land disposal. The three major aspects of waste minimization are source reduction, recycling, and treatment.

Local regulations concerning management and disposal of hazardous wastes have become more restrictive to reflect the public's "not in my back yard" attitude.

Other States and Countries

In the United States, ten states currently regulate used oil as a hazardous waste. Existing laws have not been actively enforced in all states due to lack of funds. All states encourage used oil recycling.

Fifteen years ago, Europeans stressed burning of oil wastes, while Americans stressed reprocessing. Today, however, recycling of oil wastes is being promoted on a worldwide basis. Oil waste management regulation has become stricter worldwide.

1.5 Conclusions

Regulation of used oils has become increasingly strict in recent years. This trend is expected to continue. Traditional management techniques such as land disposal and incineration for disposal have declined in popularity. This is because they can cause environmental problems and do not recycle the oil for any useful purpose. There is a trend towards recycling techniques that generate little or no waste.

Oil waste streams and applicable management options are summarized in Table 1-1. A decision tree of management options is presented in Figure 1-1. Oil waste generators must be aware of the regulations and options facing them. This can be accomplished by continued advertising and publicity by recyclers and government agencies, and by employee education and training programs conducted by generators.

TABLE 1-1. OIL WASTE STREAMS AND MANAGEMENT OPTIONS

WASTE STREAM	MANAGEMENT OPTION									
	MINIMIZATION	RECYCLING	FUEL USE	REUSE AS ASPHALT	REREFINING	PRETREATMENT	SEWER DISCHARGE	BIOLOGICAL TREATMENT	INCINERATION	LAND DISPOSAL
Lube Oils	X	X	X	X	X					
Hydraulic Oils	X	X	X	X	X	X	X	X		
Metalworking Fluids	X	X		X	X					
Transformer Oils	X	X	X	X	X					
Cooling Oils	X	X	X	X	X					
Homeowner Crankcase Oil	X	X	X	X	X	X	X	X		
Industrial Oily Wastewater	X					X	X	X	X	
Bilge/Ballast	X					X	X	X	X	
Oily Sludge	X									*
Superfund Oily Waste	X									

*Legal but not recommended because of liability and availability problems.

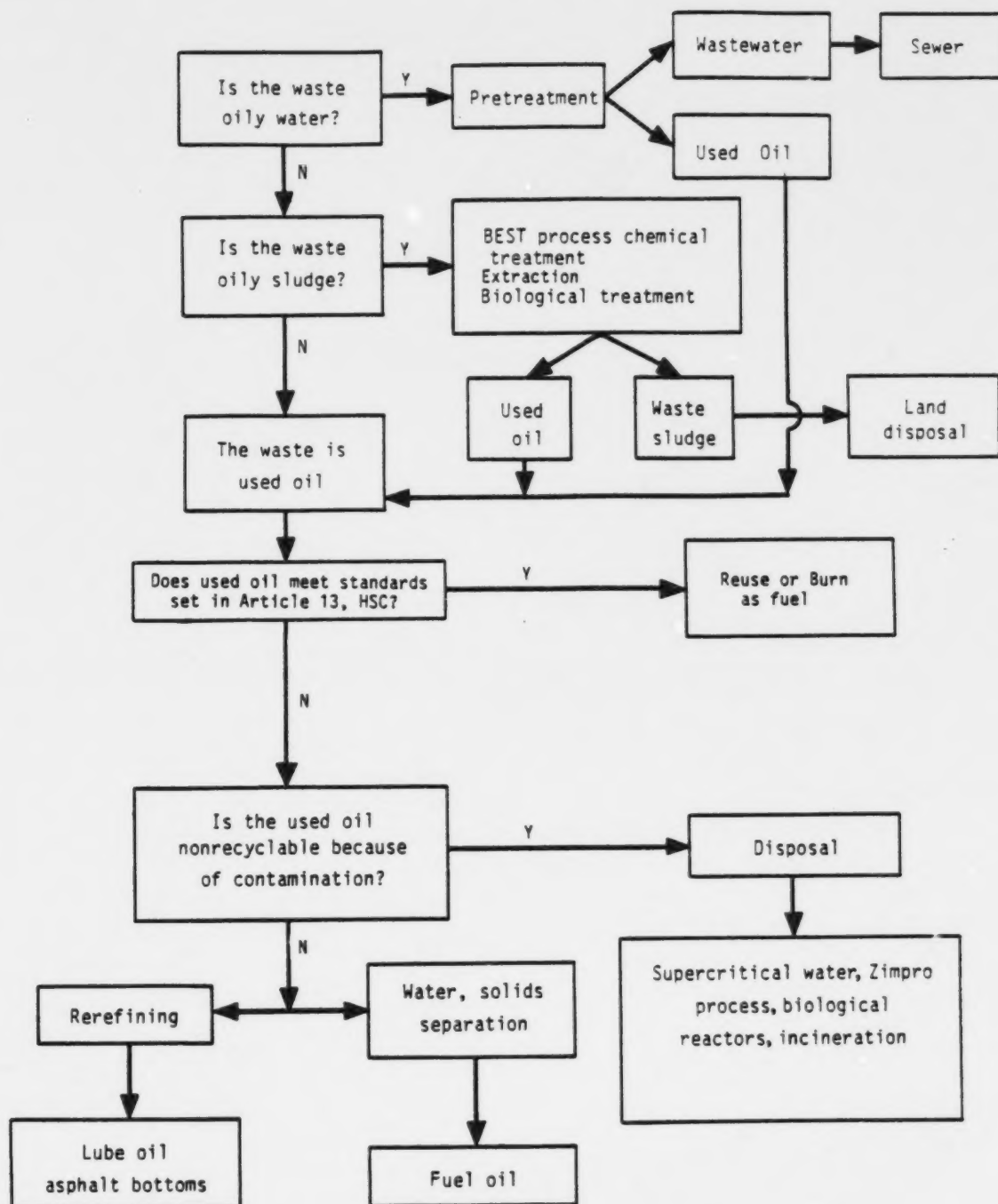


Figure 1-1. A decision tree illustrating used oil management options.

CHAPTER 2 RECOMMENDATIONS

Used oil regulations, processing technology, and management practices have evolved rapidly in recent years. The following recommendations suggest optimal used oil management practices.

Source Reduction

Source reduction is the most effective way to reduce or eliminate used oil disposal problems. Use of water soluble oils, substitution of oils, extending oil life, reformulation, use of biodegradable oils, and employee training programs are effective methods of source reduction. Source reduction employee training programs should include:

- 1) Problem definition
- 2) Reasons for changes
- 3) Description of desired practices
- 4) Specifics of new practices
- 5) Management support
- 6) Incentives for change
- 7) Follow-up to assure acceptance

In some cases, process oils such as roll oils can be eliminated by altering metal composition, metal handling, machine design or operating procedures.

Hydrocarbon-based transformer oils generally contain various quantities of PCBs as stabilizers. These oil formulations can often be replaced by non-hydrocarbon liquids such as silicones and freon-based liquids.

Waste Minimization

Waste minimization can reduce treatment and disposal costs, and can reduce reliance on land disposal. The three major aspects of waste minimization are source reduction, recycling, and treatment.

Waste Management

Generators need to be aware of the laws and options related to oil waste management. Options such as minimization and recycling can be both environmentally and economically beneficial.

In addition to being well informed, generators need to be given viable management alternatives. In order to promote sound used oil management practices, generators must have available options that do not place undue financial or technical burdens on them. Regulators and recyclers can insure that such options are available.

Biological Treatment

To maximize biodegradability of oils, it may be necessary to reformulate products to eliminate or reduce components which can inhibit biodegradation. For example, phenolic compounds and certain heavy metals are toxic to

microorganisms. Thus, if biodegradation is to be used as a disposal method, industrial users should request products without these substances.

Successful technological management options include:

- Volume Reduction - Oily wastes such as refinery sludges often contain large amounts of water. Dewatering by centrifuging or filtering can reduce the volume by 40-60 percent. The separated oily sludge may be returned to the refinery when appropriate. The water phase may be suitable for reuse. For companies that generate more than 200 gallons per day of oily waste, it is usually economical to operate water removal plants. If less than 200 gallons per day is generated, it is more economical to utilize an offsite waste management service.
- Inventory Control - Proper monitoring of inventory can reduce accumulation of overaged oil products. These products may be returned to the supplier for upgrading. Also, standard practice should include testing products received to assure their quality. Proper management of inventories can reduce or eliminate storage periods for component parts so that oil-based preservatives are no longer needed. Thus, the need to remove and dispose of used oil can be drastically reduced. Oil replacement based on contamination levels instead of time frequency can increase the life of equipment and reduce oil replacement costs.
- Elimination of Contaminants - Proper labelling, handling and overall management can significantly reduce mixing errors and resulting contamination. Use of clean tanks and vessels can avoid unwanted contamination. Proper control valves and system designs are needed to eliminate possibilities for contamination. The most important aspect of contaminant control is to prevent cross contamination of incompatible streams. This involves careful segregation of used oil streams to prevent introduction of heavy metals, solvents, halogenated organics, or radioactivity into recyclable streams. Knowledge of composition of each waste stream, properly labeled collection drums, and personnel training programs are effective ways of minimizing contaminants in used oils.
- Spill Avoidance - Careful handling procedures, use of proper equipment and training can result in a large reduction in spillage. In addition, contingency planning can minimize the severity of spills. It can also reduce volumes of contaminated oils needing disposal.

Training

Source reduction and other good management practices require personnel training. Most oil users do not fully appreciate source reduction opportunities. Once changes have been recommended, personnel need to be taught the purpose of such changes and how to implement them. Training needs to be done by someone knowledgeable in plant operations, product usage, and waste disposal. Training should include:

- Problem definition
- Reasons for changes
- Description of desired practices
- Specifics of new practices, including hands-on experience
- Management support and resources
- Incentives for change
- Follow-up to assure acceptance

Waste Audit

In order for generators of used oil to realize the full potential of source reduction practices, a site specific audit can be used. This audit should accomplish the following:

- Identify the quality and quantity of oils used
- Identify the quality and quantity of used oils generated
- Identify the sources of used oils
- Identify current handling and disposal practices
- Identify options available for source reduction
- Economic and feasibility studies of various options
- Selection of the most cost-effective and environmentally preferred option
- Detailed instructions and costs for implementation of recommended practices

DHS has available a series of industry-specific waste reduction audit manuals for small quantity generators.

Segregation and Mixing

Recycling for the original purpose or for plasticizer use requires strict segregation. For fuel usage or blending into asphalt, most used oils can be mixed together. Exceptions are those containing halogens or materials with a low flash point. If the used oil has high water percentage, care needs to be taken to assure that the blended fuel meets water limitations.

To assure proper segregation and mixing, the following recommendations are provided for generators and transporters:

- Identify the quality and quantity of oils
- Determine where used oils are generated, and by which personnel and operations
- Identify current management practices
- Select the best management option
- Plan used oils storage and transportation
- Train personnel
- Provide proper equipment and facilities
- Implement the program
- Closely monitor activities to assure that the program works properly. Provide changes as needed.

Contaminant Control

Oil replacement based on contamination levels instead of time frequency can increase the life of equipment and reduce oil replacement costs.

Recycling

Generators can take the following measures to improve recyclability:

- Identify contaminants
- Fingerprint sources of contamination
- Establish procedures to eliminate waste sources
- Set up separate waste drums for solvents and antifreeze
- Check equipment regularly for leaks
- Determine effect of temperature, pressure, and other conditions on oil life

Combustion

Combustion in unapproved or poorly performing equipment is inefficient and irresponsible. Waste oil generators should be discouraged from that. Incineration should include good incinerator design and operation. Uniform, predictable waste oil fuel properties are essential. This is enhanced by the segregation this report recommends.

Emerging Technologies

Refinements are improving the performance and economics of emerging technologies and variations of them. Competing systems will also emerge to displace established waste management systems having undesirable impacts. Generators should be continually observant for new opportunities to minimize the liabilities and costs of hazardous waste management.

CHAPTER 3 INTRODUCTION

The California Department of Health Services (DHS) has a hazardous waste reduction program to promote alternative technology and phase out land disposal. DHS contracted Energy and Environmental Research Corp. and its subcontractors, Robert H. Salvesen Associates and Evergreen Oil Inc., to conduct this study of oil waste management alternatives. This report identifies oil waste management regulations and technologies. The options described herein promote oil waste recycling and phase out of land disposal in an economically and environmentally sound manner.

3.1 Problem Definition

As a hazardous waste, used oil is subject to regulation in California. This study is concerned with industrial used oils and wastes resulting from oil usage. The following wastes are included:

- Used lubricating oils
- Used hydraulic oils
- Spent metalworking fluids
- Used cooling oils
- Used transformer oils
- Industrial oily wastewater
- Bilge and ballast
- Industrial oily sludge

Specific definitions of these terms are given in the glossary provided in Chapter 15. The study does not include wastes resulting from petroleum refining, manufacture of oil products, petrochemical manufacture, and other industrial process residues where oil is a raw material or product. The study does not include polychlorinated biphenyl (PCB) oils. A program for individual do-it-yourself (DIY) oil changers is beyond the scope of the study. Such a program could be joined with commercial or community collection programs, as discussed in Chapter 7. However, because DIYer oil frequently becomes mixed and recycled together with industrial oils, this oil is afforded some coverage.

The study is designed to inform oil waste generators of the options and constraints facing them. The primary question addressed by this study is "As a generator, what can I and must I do with my oil waste, and what common practices are not allowed?" Options for minimization, reuse, recycling and disposal are discussed. Laws prohibiting common practices such as dumping of used oil in municipal landfills are described. The study defines oil waste management regulatory constraints, technical options, economic feasibility, and environmental impacts.

3.2 Objectives of study

The primary objective of the study is to address the needs of oil waste generators. Some consideration also is given to transporters and recyclers. Generators need to be made aware of the laws and options related to oil

waste management. Options such as minimization and recycling can be both environmentally and economically beneficial.

In addition to being well informed, generators need to be given viable management alternatives. In order to promote sound used oil management practices, generators must have available options that do not place undue financial or technical burdens on them. Recyclers can insure that such options are available. Generators can then evaluate available used oil management alternatives.

The second objective of the study is to address the needs of transporters and recyclers. Used oil transporters and recyclers require viable economics and workable, enforceable legislation. It is important for every community to have used oil collection, transportation, recycling, and disposal options available.

3.3 Organization of the Report

The report is divided into three parts:

- Oil waste generation in California
- Processing technology
- Extended perspectives on oil waste management

The first part of the report, Chapters 4 through 7, characterizes oil waste generation in California. Chapter 4 characterizes the industry, the used oil stream, oil bearing wastes, and Superfund oily wastes. Chapter 5 summarizes federal and state regulations and statutes. Chapter 6 deals with onsite management techniques, including source reduction, contaminant control, mixing, and onsite management practices. Chapter 7 is concerned with used oil collection for offsite management, including existing practices and elements of successful programs.

The second part of the report, Chapters 8 through 13, describes processing technology. Chapter 8 deals with reuse of used oils and provides a technical description of individual rerefining processes. Chapter 9 is concerned with used oil combustion for disposal and energy recovery purposes. Chapter 10 describes biological oil waste treatment options. Chapter 11 deals with pretreatment of oil bearing wastewater for sewer discharge. Chapter 12 is concerned with emerging technologies and alternatives, including supercritical water oxidation, the Zimpro process, the B.E.S.T. process, and centralized waste treatment facilities.

The third part of the report, Chapters 13 and 14, deals with extended perspectives on oil waste management. Chapter 13 describes oil waste management impacts and trends, including environmental, economic, and technical considerations. Chapter 14 describes the status of used oil management in other states and countries.

A glossary of terms is presented in Chapter 15. Appendix A is an outline of unit operations. Appendix B is an annotated bibliography of references that were used during the course of the study. Appendix C is an order form for

California waste control laws. Appendix D concerns Article 13: Management of Used Oil. Appendix E defines recyclable material. Appendix F lists hazardous waste information telephone numbers.

CHAPTER 4

CHARACTERIZATION OF OIL, OIL USE, AND OIL WASTE

4.1 The Industry

The used oil industry is composed of companies and individuals who generate, transport, process/treat/recycle, and market used oil. The management of used oil begins with the generation of used oil. It flows through the collection/transportation industry into the recycling industry, where the oil is prepared for reuse or disposal. Used oil management practices of the late 1960s and early 1970s often involved unregulated land disposal and burning. These methods were wasteful of a valuable resource and harmful to the environment. Federal and state laws were passed to protect human health and the environment and to conserve a valuable national resource. Good management practices include rerefining and controlled burning for energy recovery. Undesirable management practices include road oiling, dumping, land disposal, and uncontrolled burning. This chapter characterizes used oil generators, transporters, reprocessors, and rerefiners.

4.1.1 Used Oil Generators

Many used oil generators do not recycle their oil. For example, do-it-yourself oil changers (DIYers), agricultural and construction machinery operators, and small generators of industrial oils often dump or dispose of their used oils rather than recycle them. This arbitrary management of used oil is a major problem. In addition, some generators may use their own oil as a fuel supplement or a dust suppressant. These onsite reuse practices are sometimes illegal.

In 1985, only about 54 percent, or 54 million gallons, of the 100 million gallons of used oil generated in California was recycled.

This section summarizes the management of used oils by generators. This includes onsite storage practices, onsite reuse, disposal, and offsite recycling. Generators are classified as either automotive or industrial. Automotive generators accumulate only automotive used oils. Industrial generators may accumulate both industrial and automotive oils.

Automotive Generators

Automobiles comprise millions of sources of used automotive oils in the State of California. If used oil is accumulated at a source, the source is classified as a generator. Some generators reuse the accumulated used oil onsite. However, most give their used oil to a transporter for offsite recycling.

Automobile service stations comprise thousands of used oil generators. Most used automotive oils from these generators are recycled offsite. These generators include:

Service Stations
Repair and Maintenance Shops
Vehicle Dealers
Fleet Shops
Recycling Centers

In recent years, service stations have lost their position as the major point of commercial oil changes to repair shops, rapid oil change services, and department stores.

Most of the used oil accumulated by automotive generators is generated onsite. A small amount is brought to generators by DIYers. Cleaning and degreasing solvents are sometimes improperly or accidentally put into the oil at some generator sites. Water may also enter stored oil through carelessness or faulty storage systems.

Used automotive oil generators accumulate between 50 and 2,500 gallons of used oil per month, with an average of 300 gallons. Most generators store used oil in underground tanks. Many small generators store used oil in 55-gallon drums.

Most automotive oil generators must pay to have their used oil collected. Prices vary widely depending on local used oil demand and transporter competition. In 1987, 15 cents/gal was an average price for good quality used oil. Prices varied between 0 and 50 cents/gal.

Industrial Generators

Industrial and manufacturing establishments that generate used oil are classified as industrial generators. The used oil may be recovered for reuse onsite or may be collected by a registered used oil transporter.

There are three basic categories of industrial used oil. These are straight mineral oils, emulsified oils, and synthetic oils.

The amount and type of oil and its end use depends upon the manufacturing process. For example, a metalworking facility may generate a large amount of emulsified oil through metal forming, metal removal, and heat treating processes. It may generate a smaller amount of straight mineral oil from lubricant and hydraulic applications. Other companies may generate only straight mineral oils from hydraulic systems and automotive equipment.

Because of the diversity of industrial establishments, there are hundreds of types of oil wastes. In some cases automotive used oil may be mixed with industrial oil waste. This is only common when small quantities are generated. When a large quantity is generated onsite, segregation is common. Non-oil materials, such as solvents, are sometimes mixed with oil at industrial establishments. Used oil storage containers should not be used as "catch-alls" for any liquid waste generated onsite.

An industrial facility may generate from a hundred to a hundred thousand gallons of used oil per year. Typical generation rates for straight mineral oils seldom exceed a few thousand gallons per year. Including oil emulsions, some facilities generate over a million gallons per year.

A few generators have oil inventory programs to account for oil purchases, recovery, and sales. One published report indicates that most industrial facilities cannot account for up to 50 percent of their oil purchases (3). Losses can be attributed to sloppy accounting, actual losses down drains, miscellaneous spills, oil on cloth and paper wipes, and oil included in final products.

Industrial used oil generators normally do one of the following:

- 1) treat the oil onsite for reuse
- 2) transfer all oily material to an authorized facility for processing or disposal
- 3) treat onsite to improve the quality, and then transfer the waste to an independent transporter

Onsite used oil management may be simple or sophisticated. Straight mineral oils are stored in 55-gallon drums or in steel tanks. The tanks may range from 100 gallons to 10,000 gallons. For emulsified oils, the storage requirements may be much larger. Onsite surface impoundments are used to store large volumes of emulsified oils. Tanks are generally above-ground and may be open-topped. Impoundments range widely in size and sometimes serve as treatment and disposal devices as well as storage devices.

Most used industrial oils are recycled offsite. Only about 9 percent are reused onsite. An additional 7 percent is used as a fuel supplement; 15 percent is disposed or incinerated by the generator; and less than 1 percent is used to suppress dust (3).

The price the generator pays the transporter varies from \$ 0.00 to \$ 3.00 per gallon. The price varies according to oil waste quantity and quality. Highly emulsified oils have a lower fuel and lube value and are much harder to recycle. Therefore the cost of management is higher. Larger quantities of industrial oil can often lower management costs.

4.1.2 Transporters

Transporters collect and transport used oil from generators to recyclers. Transporters are mostly independently owned operations, although some municipalities contract with truckers to collect oil from the public. Used oil transporters in California range in size from one truck to 24 trucks. California has approximately 100 companies that specialize in the collection and transportation of used oil.

Most used oil transporters are small businesses with less than five employees and less than four trucks. Often the owner is a driver, salesman, mechanic, dispatcher, secretary, and accountant all in one. The majority of used oil transporters operate out of homes, industrial yards, transfer facilities, and recycling facilities. Transporters normally collect and transport used oil in vacuum trucks. Some transporters collect and transport used oil drums.

Transporters typically operate on an on-call, as-needed basis within a certain geographic area. The calls that a transporter receives often determine the pickup route for the day. Transporters prefer to schedule

their routes in advance but generators often call when their tanks/drums are overflowing. Usually transporters can respond to an urgent call but often charge more money if the pickup causes routing problems or is otherwise inconvenient. Transporters rates in California typically range between 10 and 25 cents per gallon. Many collectors have a minimum charge per pickup and give discounts for large quantities of good quality used oil.

A transporter normally collects from a number of generators each day. Once the truck is full, the transporter delivers the used oil to a transfer station for storage or to a recycler. Some used oil transporters have their own transfer stations. These are storage tanks in industrial yards. These transfer facilities must meet required standards and be permitted by DHS. The destination of the used oil must be specified on each manifest and receipt given to the generator.

Transporters are required to manifest used oil collections. This can be done under the uniform manifest procedure for hazardous waste or the under modified manifest procedure. The modified manifest procedure allows a transporter to use one manifest for each daily load of used oil collected. These manifests are submitted to DHS in order to monitor used oil flow. Used oil transporters are also required to provide generators with either a copy of the manifest used or a receipt which contains the required information (California Health and Safety Code, Section 25250.8). Transporters are required to register with the Department of Health Services as hazardous waste transporter.

Transporters are motivated by economics. Their profit comes from generator collection fees and fees received from recyclers for delivery of feedstock. Used oil value is determined by its quality. Trucking costs are major expenditures for transporters.

Many transporters have been operating for many years and resist changes in used oil management and regulations. Operating practices of collectors range from strict compliance with all local, state, and federal regulations to flagrant disregard for existing regulations.

4.1.3 Recyclers

Recyclers are comprised of rerefiners and reprocessors. Recyclers of used oil must be authorized DHS and other appropriate agencies. A recycler normally operates a transfer station, storage facility and processing plant. The simplest facilities are steel storage tanks set on dirt. Newer facilities have secondary containment, above-ground processing and storage, on-site analytical laboratories, and 24 hour a day operation. State regulations require these facilities to provide adequate protection from the release of any hazardous constituents. This protection includes product testing, insurance, employee education, and containment.

Reprocessors

Reprocessors treat used oil to remove or reduce contaminants. The product is sold as supplemental fuel. Used oil reprocessors in California range in size from two million gallons oil per year to 18 million gallons per year.

Reprocessors generally receive used oil feedstock from independent transporters. Some reprocessors have fleets of collection trucks. Reprocessors and rerefiners often compete with each other and with independent transporters to acquire used oil.

The most common reprocessing technique uses chemical tank treatment, heat separation/dehydration and distillation. These methods can reduce contaminants in the used oil to levels that allow sale as reprocessed oil. Reprocessed oil must meet regulatory specifications. Several reprocessing methods have difficulty in removing metals.

Reprocessed oil can be sold as supplemental fuel, burned onsite, or sold as an industrial lubricant. Most reprocessed fuel oil is sold into the bunker fuel market. Reprocessors must certify that each shipment of fuel meets California recycled oil specifications. In order to verify this claim, lab results must be kept for three years. Unfortunately, few reprocessors have the laboratory equipment needed to conduct the appropriate tests.

A typical reprocessor in California operates an older facility which uses physical separation methods to process the used oil. In order to maintain a steady production rate, reprocessors must have a steady stream of used oil feedstock. This feedstock is obtained from the reprocessor's own collection fleet or is bought from independent collectors. Larger reprocessors often set up transfer stations in strategic areas in order to bulk used oil collections in large quantities before transporting the used oil to the facility. Reprocessors are motivated by economic forces and react to fuel oil market conditions. Therefore, the major emphasis is operating profitably in a volatile market.

To meet specifications, some reprocessors blend different used oils after they have been filtered and impurities have been removed. A large percentage of oil is processed in this manner. This practice is allowed in California only if conducted at a permitted treatment facility. Blending with new or virgin oil is prohibited unless the used oil meets specified standards. The resulting product is not similar to a rerefiner's product, which is essentially equivalent to new oil. However, the majority of used oil that is collected and recycled in California enters the blended fuel market.

Reprocessing Technology

Reprocessing removes some of the metals, toxic chemicals and water contained in the used oil. It is less expensive than rerefining. Rerefined oil products are primarily used for lubrication whereas the reprocessed oil products are used as fuel.

Some reprocessing techniques are simple and inexpensive processes such as gravity settling and blending. Others are complex and more costly, such as distillation and solvent extraction. The more complex processes remove greater quantities of contaminants, improving oil quality. The most commonly used processes are:

Blending: Mixes portions of used oil with new fuel oil to produce fuel oil. This practice is illegal in California unless the used oil meets purity standards (Article 13, HSC) prior to blending.

Gravity Settling: Allows heavy particles in the oil to settle over a period of time without the use of filters. The product oil is drained from the tank, leaving the heavy particles in the tank. Hazardous components such as lead, ash and chlorine may still exist in the oil (1).

Heating: Decreases the viscosity of the oil being settled, allowing more particles to settle. This allows better separation of contaminants from the used oil (1).

Filtration: Circulates oil through a series of tubular filters to remove large particles. This achieves high settling rate. At one facility, in a 24 hour cycle, an average of 80 pounds of waste was removed from 345,600 gallons of contaminated oil (1).

Solvent extraction: Removes ketones, alcohols, and hydrocarbons from the oil. Solvent is mixed with oil at room temperature and allowed to stand for 4-36 hours. The mixture is then centrifuged, decanted, vacuum distilled and analyzed by spectrometry. This method produces a hazardous liquid sludge. Residue disposal can cause problems (1).

Distillation: Removes water and light components from the oil by evaporation and stripping (1).

Solids, semisolids, and liquid residues often result from waste oil reprocessing. These sludges are normally disposed of in landfills. Some processing can be done on the residues. For example, some oil may be recovered from tank sludges by dewatering and blending. Also, sludges from the distillation process can be used for asphalt blending.

Rerefiners

Used oil can be rerefined into lubricating oil. Rerefined products are virtually identical to new oil. Composition of lube oil does not change drastically after its initial use. While in service, lube oil collects contaminants from its working environment, which decreases its lubricating ability.

Rerefining produces a much higher quality oil than reprocessing. Rerefining removes all contaminants and allows the oil to be used as a lubricant once again. This is important because only three percent of most crude oil can be refined into lubricating oil. Thus lubricating oil is a scarce natural resource.

Rerefining used oil also saves energy. The amount of energy needed to refine crude oil into virgin lube oil is twice that required to rerefine used oil. Rerefining conserves 23,590 BTU/gallon of oil (2). There are three facilities in California that rerefine used oils. These facilities range in capacity from two million gallons per year to 18 million gallons per year. Plants normally run 24 hours a day, seven days a week.

Rerefining once was a major national industry. Large scale rerefining began around 1930 and grew steadily through World War II to 1960, when output was 300 million gallons/year. The U.S. rerefining industry has been troubled by increasing costs and volatile oil market conditions since the 1960s. In 1960 there were about 150 rerefiners. By 1974, the number of rerefiners had dropped to 26. Today, only a handful remain, rerefining less than 100 million gallons annually. One closed rerefiner may reopen with a capacity of two to three million gallons (8). Rerefiners are not currently operating near capacity. The reasons for the decline are that the poor economic environment has forced smaller rerefiners out of business, and rerefined oil has a poor image. This is despite a product quality that often exceeds virgin lube quality (2).

Other reasons for the decline include:

- A tax imposed only on used oil during the early 1960s.
- The advent of discount stores selling oil directly to consumers, thus breaking the recycling loop.
- Doubts about rerefined oil quality combined with labeling requirements for rerefined oil products from 1965 to 1980.
- Rerefineries becoming obsolete in the 1960s and not being modernized.

Many of these problems have been alleviated. The quality of rerefined oil is now known to be as good as virgin lube oil. Restrictions imposed on military use of rerefined oil were lifted with the Energy Policy and Conservation Act of 1975. The government now uses rerefined oil in its vehicles. The labelling requirement was removed by the Used Oil Recycling Act of 1980.

In the past, rerefining technology generated oily wastewater or sludge. Although the same technology is still used, by-products are now treated to allow discharge to sanitary sewers or land disposal. New technology exists which generates no hazardous waste. Residues from this new technology can be used as supplemental fuel oil or asphalt extender.

Investment capital problems for the rerefining industry are diminishing. Some large companies have shown interest in the rerefining industry. Advanced technology and economies of scale are becoming increasingly important. Increased public, industry, and government concerns about proper oil waste management are providing greater opportunities for rerefining.

Rerefiners are subject to the same permitting and regulatory requirements as reprocessors. Rerefiners must maintain a steady stream of quality feedstock to operate economically and to produce a high quality product. Rerefiners have laboratories on site to test incoming used oil feedstock, as well as the outgoing product. Blenders and compounders are common purchasers of rerefined lube basestocks.

Rerefiners estimate that 75 to 80 percent of their feedstock is used engine oil. The remainder comes from industrial sources. Rerefiners have their own collection fleets or receive oil from independent transporters.

Rerefiners have heavy investments in their facilities. The technology has shifted from acid-clay polishing to hydrotreating for final finishing. Acid-clay technology generated waste by-products that were difficult and expensive to manage. New rerefining facilities are being built with state-of-the-art technology. This new technology generates no hazardous waste. It recovers approximately 69 percent of the oil present in the feedstock. By-products are gas oil and asphalt extender. Other rerefineries are being considered in response to the demand for recycling services and the economics of new technologies.

Recycling Technology

Recycling technologies can be separated into three general types of treatment: chemical, solvent, and physical. Combinations of these methods can also be used.

Chemical Treatment

- Phillips Rerefined Oil Process (PROP) utilizes diammonium phosphate to demetallize used oil. This results in a metal laden sludge which is insoluble in either oil or water. The sludge must be filtered from the oil stream. It is suitable for landfill disposal and cannot be marketed as a by-product.
- Sulfuric Acid Treatment combined with clay contacting is environmentally unacceptable because of the acidic sludge and the air emissions generated.
- Recyclon process involves chemical treatment of the used oil with finely divided sodium. The process uses flash distillation to remove water and separate out residues from the oil stream. Residues are not marketable by-products.
- Turbo Resource process is similar to the PROP demetallization step except an aqueous solution of aluminum sulfate or ammonium sulfate is used. A hydrophobic dry cake results which is suitable for landfill disposal.
- The Kozar process consists of chemical treatment with an aqueous alkaline solution of sodium metasilicate.
- The Salusinszky patented process removes metals and water from used oils by treatment with an aqueous solution of surfactant and anions. The anions form insoluble salts with the metals in the oil.

Solvent Treatment

- Methyl Ethyl Ketone process was patented by Texaco to reduce lead content of used oils. Solvent treatment of the oil produces an

insoluble sludge. This sludge is separated by settling or centrifugation. Solvent is recovered by flash distillation. The Department of Energy (DOE) enhanced the process as described below.

- DOE Solvent Process was developed at the Bartlesville Energy Technology Center. It involves treating the used oil with methyl ethyl ketone, n-butanol and isopropyl alcohol. The solvent is recovered from the sedimentary sludge by flash distillation. The complexity of the equipment makes installation and operating costs higher than most other processes.
- Supercritical extraction has been developed by the Krupp Research Institute in West Germany. Supercritical ethane removes contaminants from used oil. Pressures of 1500 psi are required to separate the oil from the solvent. Such high operating pressures require high capital investment costs.

Physical Treatment

- Heat Treatment of the used oil followed by filtration causes organometallics and other undesirable components to oxidize and fall out as sludge. Heat treatment may cause coking and fouling. This results in unreliability and downtime in an operating facility.
- Ultrafiltration through selective membranes has been tested by the French Petroleum Institute (IFP). Reductions of lead content to acceptable levels have not been achieved. This renders the process inappropriate for used oil reprocessing.
- KTI Process incorporates dehydration and vacuum distillation to remove water and sedimentary contaminants in the oil. The sedimentary contaminants are rejected into a heavy distillate and residue. The residue has excellent properties for use as a bitumen extender and is marketed to the asphalt industry. No environmentally unsafe by-products result from this process.

4.2 The Used Oil Waste Stream

4.2.1 Classification of Lubricating and Process Oils

Lubricating and process oils can be classified as either automotive or industrial oils.

Automotive Oils

A wide variety of automotive oils are used in numerous applications. Basic types of automotive oils include:

- Engine crankcase oils
- Transmission fluids, including power steering fluid
- Diesel engine oils
- Automotive hydraulic fluids, primarily brake fluids

In 1987 an estimated 1.445 billion gallons of automotive crankcase and hydraulic oils were sold (4). About 60 percent were engine oils for over-the-road cars and trucks. About 20 percent were engine oils for off-road vehicles such as farm, construction, military, and mining vehicles. Less than 20 percent was sold as transmission and hydraulic oils.

Industrial Oils

Hundreds of lubricating oil formulations are used in thousands of industrial applications. Most of these oils can be classified according to the following seven major categories:

- General Industrial
 - Hydraulic
 - Compressor
 - Turbine
 - Bearing
 - Gear
 - Refrigeration
- Metalworking (removing, forming, testing, protecting)
- Process
- Railroad Diesel
- Marine
- Natural Gas Engine
- Grease

Process oil was the largest category listed for 1987 (300 million gallons). Process oils are used in the manufacture of rubber, ink, paint, putty, polishes, as well as in electrical applications. The oil becomes an integral part of the process. For all practical purposes, it is consumed and is not available for recovery and reuse.

For specific end-use application, hydraulic oils are the largest market. Straight mineral hydraulic oils comprise about 96 percent of this market. These oils include rust and oxidation oil and antiwear oil (4). A growing market is fire resistant hydraulic fluids. These are emulsified oils containing 60 to 95 percent water. The major generators of used hydraulic oils are the steel, automobile, and mining industries. Municipal vehicles also use substantial amounts of hydraulic oils. These vehicles include snow plows, buses, street sweepers, dump trucks, and garbage trucks.

Turbine oils are similar in composition to hydraulic oils. Turbine oils are used in turbines to generate electricity and in compressors in ammonia plants, chemical plants, refineries, and other industrial plants. Turbines require expensive natural gas as fuel and are being replaced by more efficient large gas reciprocating engines. However, turbine oils will continue to be used where gas turbines have a size and weight advantage, such as in aircrafts and offshore drilling rigs.

Industrial gear lubricants usually contain extreme pressure additives to minimize wear and prevent gear damage under a wide range of speed and torque conditions. Machinery often contain gear boxes that use industrial gear lubricants specified by manufacturers. Cars and trucks use gear oils for rear axles, transmissions, and differentials.

Metalworking oils are another major industrial category (170 million gallons in 1987). They are used as lubricants for cutting, grinding, machining, rolling, stamping, and quenching steel and aluminum, and to prevent rust and staining. There are three types of metalworking oils, including straight mineral oils (neat oil - no water phase), emulsions (up to 95 percent water), and synthetic oils in emulsified form. Straight mineral oil formulations containing emulsifiers are often purchased by a user who adds water onsite. The quantity of emulsified metalworking fluids is much larger than the quantity of straight mineral oils.

Railroad and marine oils (60 and 44 million gallons, respectively, in 1987) are either cylinder or crankcase diesel oils. These differ from other diesel engine oils in both basestock characteristics and additives. Rail and marine oils vary depending upon service requirements. Natural gas engine oils are consumed in thousands of gas-driven engines used on irrigation and crude oil pumps.

Electrical oils act as heat transfer media in transformers. They maintain transformer operating temperatures below acceptable limits. Straight mineral oil, a non-conducting material with no additives, is replacing PCB oil formerly used.

4.2.2 Used Oil Generation

In most lubricating and industrial applications, the performance of the oil deteriorates over time as additives break down and contaminants build up. Eventually the oil must be replaced by new oil. Each of the thousands of specific oil applications generates used oil because of routine replacement.

The fraction of the new oil which becomes used oil varies widely. For example, only 10 percent of industrial process oils sold are generated as used oil, as compared to 90 percent of electrical transformer oils (4). The non-generated fraction is lost through leakage, spillage, combustion, disposal with equipment, and disposal due to high levels of contamination. Overall, a little more than half of the lubricating and industrial oils become generated as used oil.

A summary of estimated demand for automotive and industrial oils is shown in Table 4-1. Total automotive oil sales are somewhat higher than industrial oil sales. Sales in each major categories are broken down into specific oil applications in Table 4-1.

The used oil generation rate for automotive oils is about 56 percent, compared to 48 percent for industrial oils. The low generation rate for industrial oils is largely due to the very low generation rates for some metalworking oils, industrial engine oils, and process oils. All of these are major oil markets. 1.25 billion gallons of used oil was generated as a result of an estimated sale of about 2.5 billion gallons of oil in 1987.

Table 4-1. Estimated Demand for Automotive Oils (million gallons) (5).

	SAE J-183 Engine Oils	Other Engine Oils	Transmission & Hydraulic Oils	Gear Oils	Total
1987	1117	38	234	56	1445
1986	1106	37	232	56	1431
1985	1099	37	229	55	1420
1984	1086	36	229	55	1406

Estimated Demand for Industrial Oils

	General Industrial Oils	Industrial Crankcase Oils:			Metal- working Oils	Process Oils	Total
		RR	Marine	Gas Engines			
1987	465	60	44	40	170	300	1079
1986	460	59	43	40	170	295	1067
1985	460	59	43	40	170	295	1067
1984	460	59	42	40	170	300	1071

4.2.3 Used Oil Properties

Chemical Analysis

Lubricating and industrial oils are mixtures of hydrocarbons derived from crude oils. Crude oil can be categorized into three groups based on predominant hydrocarbon structure: paraffinic, naphthenic, and aromatic. The proportion of these three groups determines the physical and chemical properties of crude oils.

Additives are blended into most lubricating oils to enhance performance. Additives are included to: (1) protect the surface being lubricated, (2) improve the lubricant performance, and (3) preserve the lubricant. The additive package usually comprises 10 to 20 percent of the volume of the finished lubricant. Hazardous constituents in lubrication oils are often introduced by the presence and breakdown of additives.

Performance of lubricating and industrial oils deteriorate over time as additives are chemically changed, and the oil becomes contaminated from internal and external sources. Internal contamination results from the additive breakdown and subsequent reaction. External contamination can result from soot and lead from engine blowby, dirt and dust, metal particles from engine wear, rust, gasoline from incomplete combustion, water from blowby vapors, and the mixing or dumping of materials into used oils.

Automotive used oils tend to have high concentrations of potentially hazardous heavy metals. Industrial oils tend to have high levels of chlorinated solvents and PCBs. The contaminants typically found in used oils are listed in Table 4-2.

Metal Concentrations in Used Oils

Trace metals enter used oil from several sources. Most notable is lead. Lead is primarily from piston blowby in engines using leaded gasoline. Lead may also be a minor component of some antiwear/extreme pressure additives. Barium and zinc enter used oil through additive packages included in commercial motor oil. Cadmium and chromium enter oil in trace amounts, primarily as a result of engine wear. However, some additives may also contain these metals. The source of arsenic in used oil has not been determined.

Lead is present in higher and wider concentration ranges than other metals. Typically, mixed used oils in the 1980s have a lead concentration of 100 to 1,200 ppm. The concentration of lead is decreasing as unleaded gasoline replaces leaded gasoline.

Barium concentrations in used oil range from 50 to 500 ppm. Levels close to 4,000 ppm have been reported. Cadmium concentrations above 10 ppm are rare. Typical cadmium levels are around 2.0 ppm. Chromium concentrations are generally higher than cadmium. Typical chromium levels range from 3 to 30 ppm. Arsenic is sometimes detected in used oil. Arsenic concentrations range from 5 to 25 ppm when present. Zinc concentrations are high in used oils, typically ranging from 100 to 1,200 ppm. Zinc is the only metal that typically occurs at levels close to those of lead.

Table 4-2. Typical contaminants in used oils.

Metals	Chlorinated Solvents	Other Organics
Cadmium	Dichlorodifluoromethane	Benzo(a)pyrene
Chromium	Trichloroethene	Benzo(a)anthracene
Arsenic	Tetrachloroethylene	PCBs
Barium	1,1,1 - Trichloroethane	Naphthalene
Zinc	Trichlorotrifluoroethane	Benzene
Lead	Total Chlorine	Toluene
		Xylenes

Chlorinated Solvent Concentrations in Used Oils

Chlorinated solvents are major used oil contaminants. They are not a normal component of crankcase oil, but are indirectly introduced through careless management practices. For example, automobile mechanics often pour small amounts of degreasing solvents into used oil storage tanks/drums.

Five chlorinated solvents are commonly detected in used oils. These are dichlorodifluoromethane, trichlorotrifluoroethane, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene. Levels of contamination range from 100 ppm to several thousand ppm. The presence of chlorinated solvents can be measured by total chlorine. Although chlorine can be present in other forms, such as organic salts, this measure is an indicator of the potentially hazardous chlorinated substances. The data indicate that typical chlorine concentrations range from 1,000 to 5,000 ppm.

Other Organics Concentrations in Used Oils

This general category includes aromatic solvents, PNAs, and PCBs. Except for PCBs, used oils are likely to contain these contaminants.

Aromatic solvents are in used oils because of oil formulations, oil use, and mixing with spent solvents. Toluene and xylene typically range from 500 to 5,000 ppm. Levels above 10,000 ppm have been measured. Benzene concentrations are much lower and typically range from 100 to 300 ppm.

The concentration of benzo(a)pyrene and benzo(a)anthracene range from below detection levels to several hundred ppm. These PAHs are present in unused lube oils, but seem to become concentrated in used automotive oils, "apparently coming from the gasoline or diesel fuel and their combustion products" (6). Benzo(a)anthracene ranges from 10 to 50 ppm. Benzo(a)pyrene typically ranges from 5 to 20 ppm. Naphthalene is often found with ranges from about 100 to 1,400 ppm.

Although PCBs concentrations are not detectable in most used oil, they can be present in concentrations greater than 100 ppm.

Flash Point

Flash points for used oil typically are over 160 °F. They can range from below 100 to over 500 °F. The flash point for virgin oil and unadulterated used oil is normally 300 to 400 °F. This shows that contaminants can greatly affect ignitability. Virgin lubricating oils normally have flash point between 350 and 450 °F. Low flash points are due to contamination by low flash point materials such as gasoline, and chlorinated and organic solvents.

Viscosity

Viscosity is a measure of the internal friction of a liquid, or its resistance to flow. High viscosity indicates high resistance to flow. Gasoline has a viscosity of 0.5 centistokes at 100 °F. Some heavy machine oils have viscosities that exceed 2,000 centistokes. The viscosities of used oil vary with virgin oil product formulations and acquired

contaminants. Some waste oil samples are less viscous than gasoline, which probably indicates a high solvent content.

Studies have shown that used oil viscosities can range from 1 to 513 centistokes, with a median of 71 and a mean of 47.

API Gravity

The API gravity is a density parameter that can be converted to specific gravity by a conversion equation. The scale in API gravity is more precise than the specific gravity scale. In the API scale, lower values indicate more dense oil. For example, a value of 13 means that the oil is 0.98 times as dense as water. A value of 80 means that the oil is only 0.67 times as dense as water.

Used oil typically has API gravity of 25-28. Again, contaminants in the used oil directly effect API gravity.

4.3 Oily Waste

The four major types of oily waste generated in California are listed Table 4-3. Table 4-3 excludes water co-produced with oil.

All of these materials are predominantly water, containing from 0.1 to five percent oil. Thus, the problem for waste reduction is segregating out the water to permit oil reuse or disposal to municipal sewage plants or open waterways. Any oil wastes are thus greatly reduced in volume. These wastes can be recycled or economically managed.

Technology for treating oily waste is highly developed. It consists of some combination of gravity separators, oil/water coalescers, filters, centrifuges, chemical treating, flotation units, absorbents, adsorbents, extraction units, and biodegradation units (7). In addition, membrane processes are showing promise for specific small-scale applications (8). Generally, treatment steps are combined in series to gradually reduce the oil concentration to acceptable levels. Choice of treatment depends on composition, the ease of oil separation, and waste stream volume. Figure 4-1 is a processing logic chart (9). Common treating methods are discussed below for each of the major waste streams listed above. Examples of new equipment to efficiently process these dilute aqueous streams are illustrated in Chapter 8.

4.3.1 Bilge and Ballast

Bilge oil is a mixture of fuel oil, lubricating oil, and hydraulic oil (10). It is dispersed in sea water, along with dirt, rust, and bacterial sludge. The proportion of oil to water can vary, but is generally below one percent. Ballast oil composition depends on what is carried in the ballast tanks when the ship is not in ballast. Usually this is fuel oil, crude oil, or bulk petroleum products. The oil concentration in the ballast water is normally 0.1 to 1.0 percent.

The oil in bilge water and ballast usually exists as free oil droplets dispersed in the seawater or as a sheen on the water (11). Sometimes it is

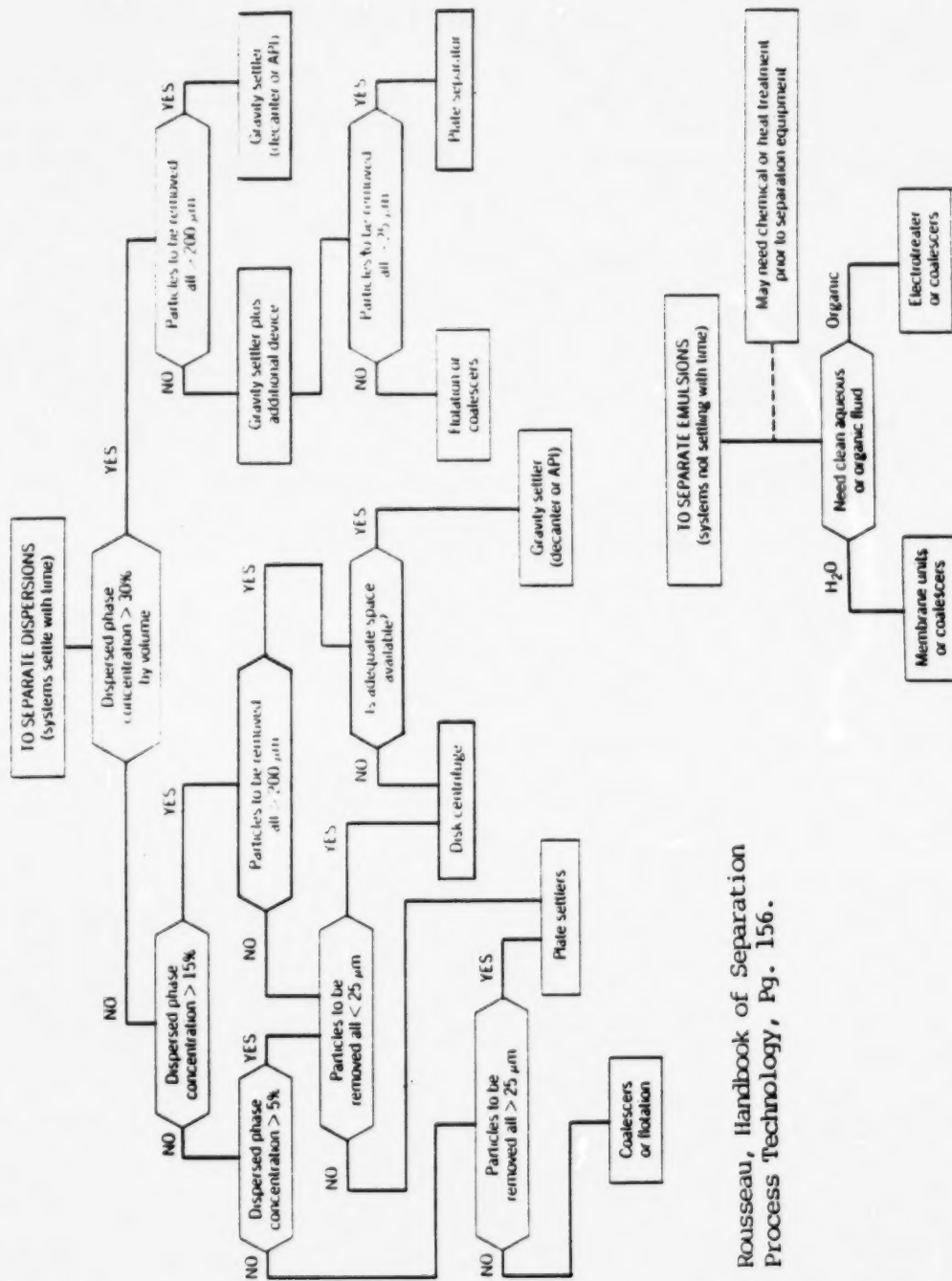
Table 4-3. Oily wastes.

Oily Waste	Approximate Volume	
	Total Vol. (gal/Yr)	Oil Volume (gal/Yr)
Bilge and Ballast	300,000,000	3,000,000 (a)
Rain Runoff	Unknown	Unknown
Washings from Cleaning Vehicles and Tanks		8,000,000 (b)
Cutting Oils	144,000,000	4,800,000 (c)

(a) Estimated from figures for Naval installations plus 50 percent.
Excludes petroleum company operations.

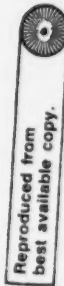
(b) Estimated from tank bottom waste in manifest history file.

(c) From July 1986 Used Oil Recycling in California report by
California Waste Management Board.



Source: Rousseau, Handbook of Separation
Process Technology, Pg. 156.

Figure 4-1. Immiscible liquid separation selection chart.



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a loose emulsion. Simple, high volume devices such as gravity settlers, filters, and coalescers are usually adequate to separate oil from the water. This permits discharge of the water to waterways.

A typical installation proposed for the U.S. Navy (12) is shown in Figure 4-2. This plan calls for initial settling of the oily water from bilge and ballast into layers of oil-free water and water-free oil. One separation method is a land-based settling tank. Another method is a water-borne vessel called a Donut. With a Donut, the settled water is directly returned to the waterway. Oily water is pumped to the Donut until either the Donut is full of oil or an oily sheen is noticed in the discharge water. Then pumping to the Donut is stopped and the Donut is moved to the oily water processing dock. The oil layer is then removed by skimming and transferred to a recovered oil tank. The oily water interface and other oily water from the Donut is then processed through an oil-water separator. The separated oil goes to the recovered oil tank while the clean water goes back to the waterway. A surge tank is used between the Donut and the oil-water separator. This allows steady operation of the separator.

If a land-based system is used for initial settling, the batch processing operation can be made continuous by drawing off the interface continuously to feed the oil-water separator. Furthermore, difficult oily water properties may require air spargers to remove noxious odors, back-wash coalescers, and activated carbon filters (12).

4.3.2 Rain Runoff

Rain runoff that carries oil from contaminated areas often can not be discharged to storm sewers. Where oil leakage or spillage is a problem, such as oil storage or oil transfer sites, the water must be collected and de-oiled before disposal. This can be done by diking large storage and transfer areas. The runoff water can be passed through a gravity settler before discharge. The oil can be collected and managed as required. Transfer sites prone to spills should have concrete paving to prevent contamination of the ground with oil. They should also have proper drainage to allow collection of the oil.

4.3.3 Washings from Cleaning Vehicles and Tanks

Autos, trucks and fuel storage tanks are cleaned with water containing detergents. This produces oily water containing solids, emulsions, free oil, dissolved oil, and detergents. Free oil can be separated by settling. The water can be filtered and reused. Detergent can be added to maintain the solution cleaning power. Filter cake and settled sludges can be disposed to landfills. Spent detergent solution can be discharged to a waste management service.

4.3.4 Cutting Oils

Aqueous waste generated by metal forming and cutting operations can be minimized by extending oil life. Fluid life can be extended by cleaning and recycling close to the generating source. An excellent discussion of this problem has been given by Kohl, et al. (8). This reference is not readily available, so the discussion is essentially reproduced below.

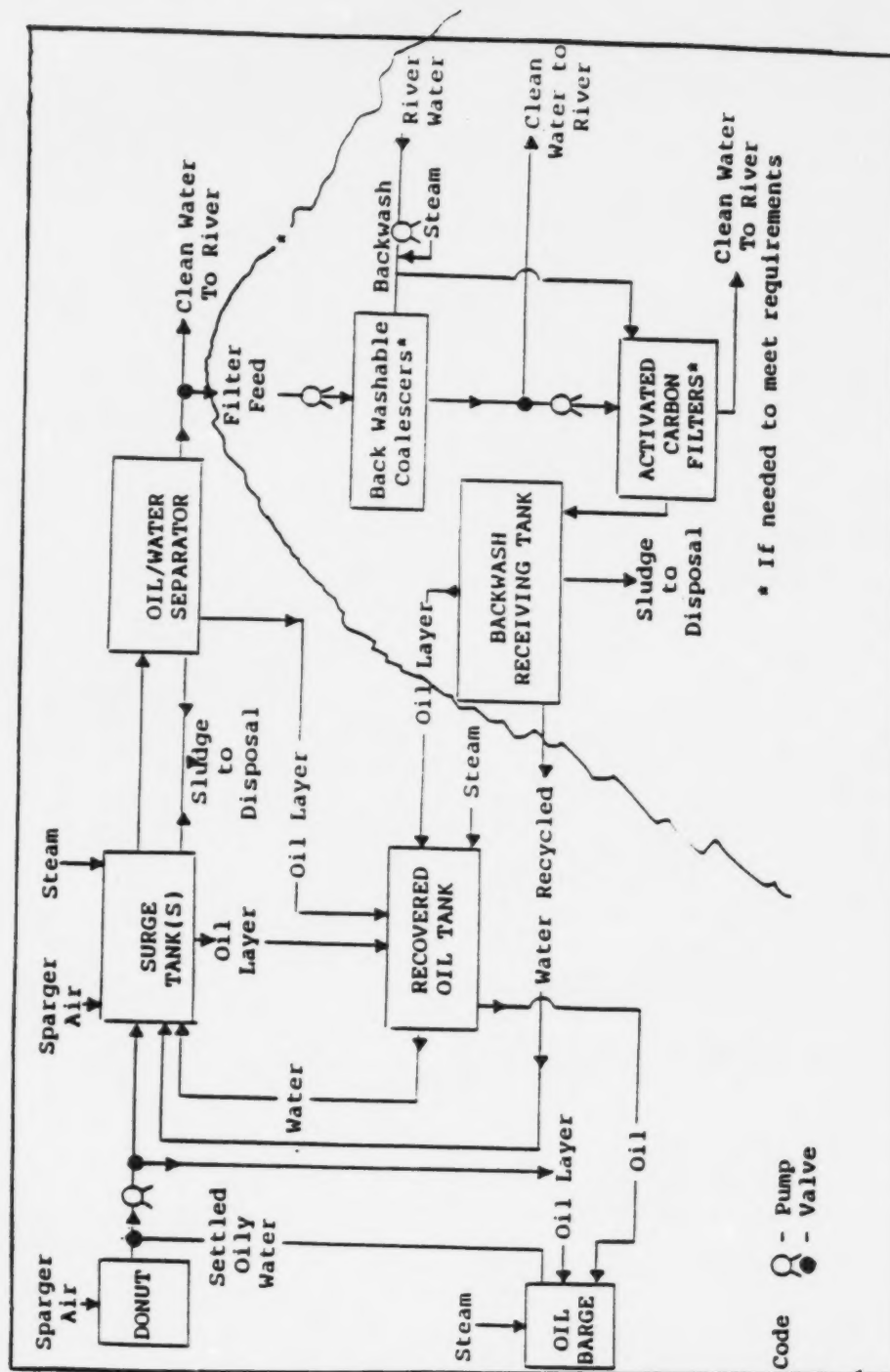


Figure 4-2. Oily water processing system.

Metalworking fluids are used for both lubrication and cooling in various machinery processes such as cutting, grinding, stamping, and milling. These fluids are divided into three classes; soluble oils, semi-synthetic oils, and synthetic oils. Soluble oil is composed of 30 to 90 percent oil in the concentrated form. When the oil is diluted with water for various industrial uses, the oil-water mixture forms a stable emulsion. Tramp oils are unwanted oils that enter a system and float on the fluid surface or mix with the fluid, going into the emulsion and thus contaminating the fluid.

The second type of metalworking fluid is termed the semi-synthetic fluid. This fluid contains 1-30 percent soluble oil in concentrated form. This emulsion is much tighter, thus making it more difficult for tramp oils to enter the system.

The final type of metalworking fluid is commonly termed the synthetic. This synthetic contains 0-1 percent soluble oils. Tramp oils are rarely able to penetrate this type of system.

Tramp oil is the common name given to all unwanted oil which enters a metalworking fluid stream or reservoir. The tramp oil most often comes from lubricating oil. Basically tramp oils occur in three forms: 1) free oils, 2) mechanically emulsified oils, and 3) chemically emulsified oils. Free oils consist of large droplets which are easily separated by gravity in an area of little turbulence. Mechanically emulsified oil is created when free oil is dispersed in a metalworking fluid, often due to the pumping action of the machine tool. Chemically emulsified tramp oil is unwanted oil which is held in suspension by chemical emulsifiers. This tramp oil is the most difficult to remove. Tramp oil causes several problems. First, it can become contaminated with bacteria which breaks down the oil and forms hydrogen sulfide which has a bad odor. The tramp oils can also carry dirt or hazardous contaminants into the clean fluid. Finally, tramp oil can enter some emulsions and cause a subsequent breakdown of fluid qualities. The most common and cost effective way to remove tramp oil is to collect the contaminated fluid in a reservoir and skim the lighter tramp oil off the top. The skimming procedure is discussed along with the other treatments below.

As was mentioned above in Section 4.3 for oily wastes in general, recycling and purification processes most commonly rely on the physical properties of waste fluids when removing contaminants. Various life extension and volume reduction processes for metalworking fluids use the same unit operations that are used to clarify oily wastes in general. These include: 1) time settling, 2) filtration, 3) ultrafiltration and reverse osmosis, 4) magnetic separation, 5) centrifugation, 6) hydroclone separation, 7) distillation, 8) aeration, 9) pasteurization, 10) chemical treatment, 11) biological treatment, 12) carbon adsorption, and 13) coalescing. Each method is used when the situation dictate it as the most efficient and economical method. Although each method can be used independently, it is more common to see several operating in series. The following sections explain the desired characteristics and preferred situation for the use of each unit operation. The advantages and disadvantages of each operation are given in Table 4-4. Figure 4-3 gives the schematic representation of many of these unit operations.

TABLE 4-4. COMPARISON OF UNIT OPERATIONS

Technology	Advantages	Disadvantages
Gravity Separation	- Economical - Simple, easy, nonskilled operation	- Limited removal of emulsified oils - Efficiency limited - Will not remove soluble oils - Slow
Filtration	- Wide range of costs - Equipment readily available - Broad applicability - Handles high solids stream - Solids down to 0.2 microns can be removed.	- Easily bound - Requires pumping energy - Needs backwashing, regeneration, or new media - Labor intensive
Magnetic Separation	- Does not remove additives - Selectively removes ferrous materials	- Only ferrous materials removed
Centrifugation	- Handles large volumes - Fast way to separate solids, free oils, and mechanically emulsified oils - Good pretreatment for emulsion breaking techniques	- High initial cost - Clean-out is difficult - Energy intensive - Noisy
Hydroclone	- Good pretreatment for emulsion breaking - Low cost - Large volumes can be handled - Effectively removes solids	- Not effective for removing emulsified or soluble oils - Some liquid rejected with solids

TABLE 4-4. (Continued)

Technology	Advantages	Disadvantages
Vacuum Distillation	- Removes water and light ends from petroleum products	- Energy intensive - Not good for high water content - High initial cost - Solids stay in oil layer - Some water usually stays in sludge layer
Ultrafiltration	- Handles wide pH range - Separates soluble and emulsified oils - Volume reduction up to 97 % - Operating temperature up to 120 F. - No chemicals - Broadly applicable to waste water streams - Continuous operation with minimal attention	- High initial cost - Energy intensive - Low flux rates - Membrane fouling possible - Not practical for large volumes of oil and grease
Chemical Treatment	- Jar test predicts scale-up - Handles high solids content - Breaks soluble oil emulsions	- Large amount of sludge (floc) produced - Often not cost effective
Carbon Adsorption	- Removes soluble oils - Filters out very fine particles	- Expensive, requires extensive pretreatment - Energy intensive - Regeneration necessary
Coalescing Plate Filters	- Low energy requirement - Handles high volumes - Efficient - Good for mechanically emulsified oils	- High solids fouling - Potential biological fouling - Economics depend on fouling

TABLE 4-4. (Continued)

Technology	Advantages	Disadvantages
Aeration	- Handles high solids content - Reliable, easy operation - Effective over range of loading	- Requires chemicals and sludge disposal
Skimming	- Low cost - Many options in equipment (belts, wheels, etc.) - Cost effective for tramp oils or free floating oils	- Not effective on emulsions or soluble oils

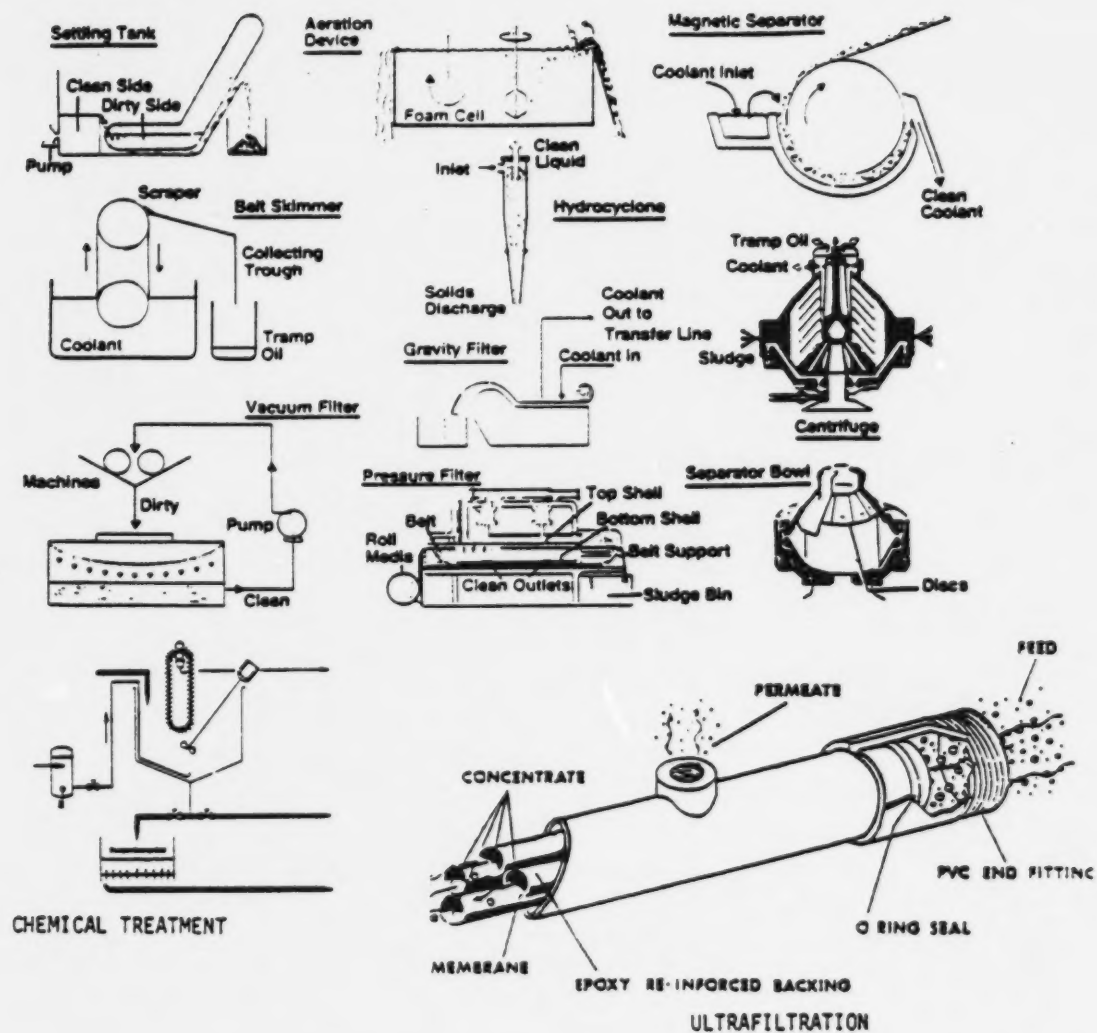


Figure 4-3. Schematics of unit operations.
(Source: Kohl, et al.)

4.3.5 Life Extension Unit Operations

Time/Gravity Settling

Time settling or retention is the simplest and most common separation technique. Time settling uses a holding device to contain a dirty fluid. The specific gravity of various solid contaminants allows them to drop to the bottom and "settle out". The lighter components, usually tramp oils, float to the top of the holding tank where they can be skimmed off. When the heavy particulates have settled, manual or automatic operations can be used to remove the settled wastes. Manual cleanout is time consuming, labor intensive, and a certain amount of downtime is required while the cleaning operation is taking place. Automatic cleanout usually involves a conveyor belt with blades which pull the solids up an incline (45-60 degrees) and releases them into a disposal container. The dirty fluid inlet is positioned near the middle of the tank's liquid level to let the heavy particulates fall out and the flotsam (tramp oil) rise to the top. The clean fluid outlet is usually positioned at the opposite end from the dirty fluid inlet.

Weirs and baffles are used to extend the separation time, control turbulence, and minimize settling distance.

While retention chambers are simple and popular, there are some cases in which they are inappropriate. First, when the contaminated fluid is extremely viscous and settling time is very long, retention chambers are impractical. When the particulate matter is extremely fine, the settling time is once again greatly increased. Certain wastes clog the bottom, sides, baffles, and weirs, thus changing the desired flow characteristics within the chamber and reducing effectiveness.

While retention chambers are sometimes used alone, they can be used in conjunction with other separation devices to reduce retention time and effect better separation. In these cases the retention tank is used primarily to remove large particulates before the fluid enters a second separating device.

Filtration

Filtration is one of the most widely applicable and commonly used purification techniques. Conventional filters can be categorized into two classes: unaided and aided filters. An unaided filter is able to use the cake (buildup of old contaminants) as a filtering medium. An aided filter must use an added filter aid to induce filtration. The three most common filter aids are diatomaceous earth, Fuller's earth, and wood cellulosic material. Aided filters are normally used in situations where contaminant levels are low and a pure product is desired. Typically, aided filters can filter down to as low as two microns. Often industries use disposable paper media which can be disposed of along with the contaminated cake when the cake becomes too thick.

Conventional filters can be subdivided into surface filters and depth filters. Surface filters hold the undesirable species on top of the media. Depth filters hold the contaminants in the interstitial spaces in the cake.

The driving forces that cause the filtration process to take place include gravity, vacuum suction, and pressure. Filtration must take many process variables into account, depending on the situation at hand.

Magnetic Separation

Magnetic separation is especially effective for clarifying metalworking fluids. This method involves separating solid ferrous contaminants from used metalworking fluids by inducing a magnetic field around a collection device. The collecting device releases the waste particles by either a break in the magnetic field or a scraper on the collector.

Centrifugation

A common unit operation used for the separation of both solids and oil from aqueous fluid is centrifugation. A centrifuge consists of a series of conical disks stacked on top of each other. The disks spin at high velocities. Each disk contains peripheral holes to let fluid rise through. As the centrifuge spins, the solids and oil sludges are "whipped" toward the outside walls by centrifugal force. The clean fluid rises through the holes and is collected midway in the centrifuge by a collection tube. Oil, the lightest component, rises through the middle and is collected at the top of the centrifuge. The wastes which collect on the periphery of the centrifuge may be cleaned manually or automatically. Manual cleaning of a centrifuge is labor intensive, since up to 30 disks must be cleaned and the cake which builds up can often be difficult to remove. This manual cleaning must be done every few uses, depending on the amount of contaminants. Automatic cleaning is preferred if large volumes must be handled to maximize efficiency of a steady state operation. This automatic cleaning process involves rapidly purging the solid waste with either high pressure probes or mechanical probes at regular intervals.

Hydroclones

Hydroclones operate with centrifugal force, much as centrifuges do. The contaminated fluid enters the top of a conical tube. A whirlpool effect takes place. The solids are pushed out to the sides and down the conical tube until they reach a small opening in the tube's bottom. The centrifugal force produced in the cyclone can separate solids down to 5 microns. These solids pass through the opening while the lighter liquid layer goes up to an overflow. While unable to produce the same amount of centrifugal force as the centrifuge, the hydroclone's popularity arises from its relative effectiveness in separating large solid particles simply and economically.

Vacuum Distillation

Vacuum distillation is most commonly used on straight oil fluids. The process uses a distillation column to remove water from the desired oil layer by creating a low temperature (140 °F or less) vacuum within the column. The low temperature keeps the oil from oxidative breakdown. A prefilter is usually necessary to remove solids. Manufacturers of vacuum distillation equipment indicate the units can handle streams containing from 5 to 40 percent water. Removing over 40 percent water with this technique would require excess time and energy and therefore be uneconomical.

Coalescing

Coalescing is a popular method of gravity separation for emulsified oils. This operation involves pumping the waste fluid through a series of coalescing plates. Oil droplets deposit on these plates. They then rise to the surface and are skimmed off. Occasionally heavy particles do not coalesce, and therefore have to be removed using an alternate method.

Skimming

Skimming uses roll, drum, or belt equipment to remove almost all "free oils" from waste streams. The oily waste which is skimmed off can then be consolidated for further disposal. Skimming is often used in series with other unit operations such as gravity separation (coalescing), filtration, and biological or chemical treating.

4.3.6 Treatment of Metalworking Fluids

Recycling of used metalworking fluids to extend their life is often an economical and practical management option. However, due to large quantities of suspended solids, rancid odor, or product degeneration, these fluids ultimately require treatment. When the amounts of oily wastewater exceed 200 gallons per day, it usually becomes economical for a plant to maintain its own treatment facility. Several widely used methods of treatment are membrane separation, chemical treatment, biological treatment, and carbon adsorption.

Membrane Separation

Membrane separation processes include reverse osmosis and ultrafiltration. Reverse osmosis uses a semipermeable membrane to separate contaminants from the waste stream. The stream to be clarified must have a pressure of 200-600 psi. Most of the permeate passing through reverse osmosis processes is suitable for sewer discharge. Usually, the sensitivity of the membrane makes reverse osmosis impractical for use with even moderately contaminated fluids. A prior treatment method is normally desired.

One such treatment method is ultrafiltration. Ultrafiltration is a membrane separation process used primarily to remove emulsified oils from wastewater. This process involves passing a contaminated stream parallel to a series of semipermeable polymeric membranes. The polymeric membrane is used under moderate pressure (up to 50 psi.) and high flow rates. This preferentially separates materials down to 0.001 microns with high molecular weights (oils and additives) by size, shape, and chemical structure. Under normal conditions the membranes must be cleaned weekly. Although ultrafiltration removes free oils effectively, these are more economically removed by skimming or some other drag-out system. Several factors which could warrant ultrafiltration are: (1) it works over a broad range of temperature and pH values, (2) no chemicals are needed since the process is a physical separation, and (3) waste volume is reduced by 95 to 97 percent. The volume handled by ultrafiltration systems is much less than that of conventional filters.

Chemical Treatment

The most widely used method for treating waste oil emulsions, such as metalworking fluids, is chemical treatment. The most common chemicals for breaking emulsions are acids, bases, and precipitating agents such as aluminum sulfate, ferric chloride, and ferric sulfate. The acid is added to the mixture to reduce pH to 4 or less. Next, the precipitating agent is mixed in and the pH is raised by adding a basic solution. Metal hydroxide precipitates out as a "floc." Floc attaches itself to other particles, such as oils, and absorbs them. The clarification process is complete when the oily floc is removed either by settling or floating. Often water clarification is sufficient to allow the clarified water to be sent to the municipal sewer plant.

Most metalworking fluids contain negatively charged particles which help hold oils in the emulsion. The chemicals for creating floc mentioned above uncharged inorganics with relatively low molecular weights. However, high molecular weight, positively charged organic molecules, known as polymers, can be added to the anionic emulsion to neutralize the solution and break out oils and solids. These oils and solids act as the floc. The advantages of using such polyelectrolytes are that a pH change is not necessary and less sludge is produced. Cost is the main drawback.

Carbon Adsorption

Carbon adsorption removes oils and other organics that have not been removed by pretreatment steps such as emulsion breaking and ultrafiltration. Activated carbon is able to handle pretreated streams with up to 50 ppm suspended solids and 10 ppm oils. Usually, several carbon beds are used in series. Carbon beds must be regenerated periodically.

Biological Treatment

Biological treatment of oily fluids is another treatment option. Both aerobic and anaerobic bacteria can be used to consume the oil. It is common to have these bacteria in both small reactors and large stabilization ponds. The bacteria form a biological floc for decomposition reactions. Typical results show up to 90 percent removal of suspended solids. Ponds and lagoons where the decomposition takes place can be quite large.

4.3.7 Economics

Cost effectiveness is the key principle in choosing the type and method of purification. The various options which are available for reclaiming and disposing of fluids have been discussed above. This section discusses the feasibility and economics of two common operations.

When sewer discharge is the desired option, the fluid is generally treated as an oily wastewater. When the volume of wastewater exceeds 200 gallons per day, it becomes more economical to operate a treatment plant than to have the waste hauled away. The technique with the lowest capital cost is chemical treatment with acid-alum or a high molecular weight polymer. The only process equipment absolutely necessary is a holding tank, such as a 55 gallon drum. However, to have a system which is less expensive than

contract hauling, the following minimum criteria are usually met. The equipment must consist of a tank which 1) can contain 500 gallons (minimum), 2) has a diameter to depth ratio of 1:1, 3) has a mixer, and 4) has a drain. Systems such as this require moderate initial costs. For example, a system capable of treating 1000 gallons per day costs about \$20,000.

An alternative generally regarded as more economical than chemical treatment is ultrafiltration. The drawback to ultrafiltration is its high initial cost. A system capable of handling 1000 gallons per day of wastewater would cost at least \$50,000. However, once the system is in operation, the system has no associated chemical costs. Generally, it is noted that ultrafiltration has an associated (noncapital) cost of 6 to 9 cents per gallon to obtain the desired 90 percent volume reduction (8).

A volume of less than about 2000 gallons per day is most economically treated by ultrafiltration. A comparison of ultrafiltration with chemical treatment for a 1000 gallon/day plant operating 250 days per year shows ultrafiltration to be about 20 percent cheaper than chemical treatment. This is based on an estimated treating cost of 12.8 cents per gallon for ultrafiltration and 16.6 cents per gallon for chemical treating. This illustrates that high initial cost is not always the most important consideration when purchasing recycling equipment. As with all unit operations, simple modeling can be used to experiment with different combinations of treatment units and the economics of their operation. Techniques such as this should always be employed before deciding to purchase a system.

4.3.8 Conclusions and Recommendations

When generating more than 200 gallons per day of oily waste, onsite waste reduction is usually economical. Generators can clean up the oil for use as fuel or recycle it. If less than 200 gallons per day of oily waste is generated, it is most economical to transfer the stream to an offsite recycler.

A large number of efficient, compact oily waste separators have recently become available. Ultrafiltration units are generally competitive with each other, differing mainly in initial cost, chemical usage, and sludge production.

4.4 Superfund Oily Waste Water and Sludge.

In 1980 Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The act determines who is financially responsible for the clean up of hazardous waste sites which pose a threat to human health and the environment. A fund was established to assist in the clean up of sites where the costs would exceed the liability of the responsible parties, or where no responsible party can be located. This fund is called the Superfund. The act is referred to as the Superfund Act (13). The CERCLA provisions were extended and clarified in the Superfund Amendments and Reauthorization Act (SARA) of 1985.

Superfund regulations affect the handling of oil wastes in three areas (8):

- Spills and accidental releases
- Leaky storage tanks
- Abandoned storage facilities.

The oils associated with the last area may differ from those discussed previously in this chapter because they are not generated directly through oil use. Oils from abandoned storage facilities fall into one of three categories:

- Abandoned tank pumpings
- Abandoned drummed oils
- Sludge pit residues.

The composition of the oils in each of these categories can vary significantly from site to site. Composition must often be determined by careful analysis. Over time the oils in tanks and drums absorb material from the walls of the container. This process is exacerbated by corrosion due to seasonal temperature variations, rain, and mechanical abrasion. Thus the oils from Superfund sites contain high levels of contaminants. The oil may also have been diluted by water infiltration. Sludge pit residues contain high concentrations of solids. In order to fall under Superfund jurisdiction the sites must present a danger to the public or the environment. Thus the emphasis is on the quick and inexpensive disposal of the materials rather than recycling and reuse. However, SARA now requires that alternative technology be considered in the cleanup process.

Several disposal techniques can handle the unusual characteristics of Superfund oily wastes. Thermal destruction is commonly used. However it is very expensive. The expense results from a combination of factors. Superfund oily wastes have low heat contents. Thus auxiliary fuels must be used. Incinerators must be mobile because few Superfund sites are large enough to support a permanent installation.

One of the simplest and least expensive alternative methods involves the in situ biodegradation of the oils (14). This technique is useful in the cleanup of sludge pits with low oil concentrations. Other biological techniques are used to treat the wastes removed from Superfund sites. These techniques are identical to the techniques described in Chapter 10 for biological treatment of used oils.

Supercritical water oxidation is well suited to the treatment of oily wastewaters from abandoned tanks and drums. As is described in Chapter 12, this process can effectively destroy the organic material in mixtures with high water concentration. It can convert inorganic materials to easily managed salts (15).

The basic extraction sludge treatment (BEST) process can effectively remove the organic material from sludges. The process employs the inverse miscibility properties of aliphatic amines to remove the organics from the sludge. The BEST process has been used to successfully treat the sludges from a Superfund site in Georgia which were contaminated with acids, oils and PCBs (16).

There are also other emerging technologies for treating oil-contaminated soils. Hydrocarbon soil washing is one technology currently being investigated by DHS Alternative Technology Section. Other technologies include in situ vitrification, steam stripping, and chemical stabilization/fixation.

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CHAPTER 5 REGULATIONS AND STATUTES

Several types of regulations and statutes govern the management of oil waste. These include hazardous waste, air pollution, and water pollution control requirements. Waste managers should be familiar with each set of applicable requirements. This chapter presents a general overview of the hazardous waste control requirements. Other regulations and statutes generally applicable to oil waste management are highlighted.

This chapter provides only a summary of the relevant statutes and regulations. Persons involved in regulated activities should become familiar with the applicable regulations and statutes. If needed, additional help can be obtained from the agencies listed in Appendix G.

5.1 Federal and California Hazardous Waste Control Requirements

This section summarizes some of the existing California and federal hazardous waste control laws and regulations dealing with the management of used oil. At the present time, California laws and regulations applicable to used oil are generally equivalent to, or more stringent than, the corresponding federal laws and regulations. There is an exception discussed below. Therefore, the state laws and regulations essentially supersede their federal counterparts in California [Section 25159.5 (b), Health and Safety Code (HSC)]. Accordingly, the state laws and regulations precede the federal in the following discussion. The federal and state laws and regulations discussed below are subject to change without notice.

5.1.1 California Statutory/Regulatory Requirements

California state hazardous waste control laws appear chiefly in Chapter 6.5, Division 20, California Health and Safety Code (HSC). State hazardous waste control regulations appear chiefly in Chapter 30, Division 4, Title 22, California Code of Regulations (CCR). The California Department of Health Services (DHS) is the state agency primarily responsible for implementing the state hazardous waste control laws and regulations. Appendix C has information about obtaining copies of the current state hazardous waste control laws and regulations administered by the DHS.

California Department of Health Services Requirements

Since 1977 "waste oil" has been listed and regulated by the DHS as a hazardous waste in California under the laws and regulations cited above (Section 66680 (e), CCR). As such, waste oil has been subject to all applicable state laws and regulations pertaining to hazardous waste generation, storage, transportation, and facility operation for more than ten years. In 1986 the California Legislature enacted Senate Bill (SB) 86 which modified the state requirements applicable specifically to the management of "used oil", which is essentially the same as "waste oil." SB 86 became state law on January 1, 1987. Among other actions, the new law added Article 13 to Chapter 6.5, Division 20, HSC, which generally:

- Defines "used oil" and provides examples of what "used oil" is and is not (Section 25250.1 (a), HSC);
- Defines "recycled oil" by specification and description (Section 25250.1 (c), (d), HSC);
- Provides a regulatory exemption for "used oil" which meets "recycled oil" specifications (Section 25250.1 (e), HSC);
- Prohibits the contamination of used oil with other hazardous wastes, and prohibits the acceptance of used oil which has been so contaminated (Section 25250.7, HSC);
- Prohibits the discharge of used oil to sewers or land, etc., and prohibits the incineration or burning of used oil, unless otherwise authorized by law (Section 25250.5 (a), HSC);
- Prohibits the use of used oil as a dust suppressant or weed control agent (Section 25250.5 (b), HSC);
- Establishes an optional modified-manifest procedure for transporters of used oil (Section 25250.8 (b), HSC);
- Exempts from DHS' permit requirements, facilities that receive and store used oil from consumers and from other used oil generators, as specified (Section 25250.11 (a), HSC);
- Requires used oil recyclers to obtain a hazardous waste (or resource recovery) facility permit from DHS (Section 25250.16, HSC); and
- Exempts from hazardous waste hauler regulations, refuse removal or curbside collection services collecting household used oil (Section 25250.15, HSC).

Unless one or more of the above provides otherwise, used oil is generally regulated by the DHS under SB 86 (1986) as hazardous waste, regardless whether the used oil is destined for recycling or disposal (e.g., Sections 25250.4, 25250.23, and 25250.24, HSC). The full text of the HSC provisions of SB 86 (1986) is reproduced in Appendix D of this document for reference.

The following paragraphs set forth some of the specific requirements (paraphrased here) of SB 86 (1986) and related state laws and regulations as they apply to generators, transporters and facility operators who manage used oil in California.

A generator of used oil must usually:

- Store his or her used oil in compliance with the temporary-storage requirements for generators of hazardous waste, if he or she stores the used oil no longer than 90 days, as specified (Section 25123.3, HSC and Section 66508, CCR). However, he or she may accumulate for one year or less as much as 55 gallons of hazardous waste, including used oil, in containers at or near any point of

generation without complying with the temporary-storage requirements, if the containers are labeled and managed properly, as specified (Section 25123.3, HSC).

- Apply for and obtain a hazardous waste storage facility permit (Section 25201, HSC) if he or she:
 - Stores his or her used oil and/or other hazardous wastes in tanks for any period of time, and the quantities stored exceed 5000 gallons or 45,000 pounds, whichever is greater, as specified (Section 25123.3 (a) (2), HSC); or
 - Stores his or her used oil and/or other hazardous wastes longer than 90 days, as specified (Section 25123.3 (a) (1), HSC).
- Properly identify his or her used oil on the manifest (Section 25160 (b), HSC and Sections 66471 and 66482, CCR).
- Either comply with the full manifest requirements for generators of hazardous wastes (Section 25160, HSC), or qualify for and consent to the transporter's use of the modified-manifest procedures discussed below (Section 25250.8, HSC). However, if the used oil is destined to be burned for energy recovery at a facility authorized by DHS and contains more than 1000 ppm total halogens, then the used oil is presumed to have been mixed with hazardous waste. A generator of that used oil generally could not qualify for the modified-manifest procedures, because federal regulations (discussed below) require such oil to be transported under a full manifest as if it were a hazardous waste. The presumption of mixing is apparently the only case where federal laws and regulations are more stringent than California's corresponding laws and regulations regarding used oil. (See Sections 266.32 and 266.40 (c), Title 40, Code of Federal Regulations (CFR) and Section 25159 et seq., HSC).
- Retain for three years copies of manifests and/or copies of receipts for all used oil shipped under the modified-manifest procedures discussed below (Section 25250.8 (b) (5), HSC and Section 66492 (a), CCR).
- Ship his or her used oil via a registered hauler using certified vehicles to a recycling facility or disposal site authorized by the DHS to accept used oil. See transporter and facility owner/operator requirements below.
- Ensure that used oil destined for disposal conforms with the state laws and regulations pertaining to land disposal restrictions (Sections 66480 and 66905, CCR) and to land disposal of liquid hazardous wastes (Sections 66480 and 67422 CCR). State statutory requirements for incineration of hazardous wastes having a heating value greater than 3,000 Btu/lb and requiring disposal were postponed until January 1, 1990 (Section 25155.5, HSC and DHS policy).

- Be prepared to justify to the DHS' satisfaction upon DHS' request that used oil destined for disposal could not be recycled (Section 25175, HSC and Sections 66763 and 66796 (b) (3), CCR).
- Comply with generator biennial-report requirements for generators of five tons or more per year of hazardous wastes, including used oil (Section 66493, CCR and DHS policy).
- Comply with other applicable recordkeeping and related requirements [e.g., obtain an EPA identification number as a generator of hazardous waste, as specified (Section 25250.24, HSC and Section 66472, CCR)].

A transporter of used oil must usually:

- Register with the DHS as a hazardous waste hauler (Sections 25163, and 25250.23, HSC, and Section 66428, CCR).
- Have his or her vehicle(s) and/or container(s) certified by the California Highway Patrol (CHP) (Section 25167.1 et seq., HSC, and Section 66434, CCR).
- Comply with the full-manifest requirements for transporters of hazardous wastes (Section 25160, HSC and Section 66541, CCR), or, if the generators qualify for and consent to its use, comply with the modified-manifest procedures set forth in SB 86 (1986) (Section 25250.8, HSC) and summarized below:
 - Use a separate manifest per driver, per vehicle, per day;
 - Complete the manifest as if the transporter were the generator, as well as the transporter, of the used oil;
 - Attach to the front of the manifest, legible receipts which have been signed by the generators and which identify each generator, his or her used oil, and its destination, as specified;
 - Provide a copy of each receipt to each generator, respectively;
 - Identify on the manifest the cumulative total quantity of used oil (from all generator receipts) transported under that manifest to a designated facility;
 - Obtain an authorized representative's signature and date of receipt at the designated facility;
 - Submit the generator's copy of the manifest (not the receipts) to the DHS within 30 days of shipment; and
 - Retain a copy of the manifest and all receipts pertaining to that manifest for three years.

- Report to the DHS annually the quantities of used oil transported during the preceding calendar year and other specified information (Section 25250.10, HSC).
- Comply with other applicable requirements for transporters of hazardous wastes (Section 25250.23, HSC).

A facility owner or operator who accepts used oil must usually:

- Obtain a hazardous waste or resource recovery facility permit from the DHS to dispose of, treat, or recycle used oil, as applicable (Sections 25201, 25250.16 and 25250.24, HSC and Section 66802, CCR).
- Ensure that used oil destined for disposal conforms with the applicable state laws and regulations pertaining to land disposal restrictions (Sections 66480 and 66905, CCR) and to land disposal of liquid hazardous wastes (Sections 66480 and 67422, CCR).
- If he or she recycles used oil, report to the DHS annually by March 1 of each year the quantities of used oil received, recycled and/or possessed, as specified, during the preceding calendar year (Section 25250.17, HSC).
- Comply with other applicable reporting and related requirements for owners or operators of hazardous waste and/or resource recovery facilities (Section 25250.24, HSC).

The above stated requirements generally do not apply to persons in California who manage used oil which meets the standards and criteria of purity for "recycled oil" as specified in SB 86 (1986) and as reproduced in Appendix D. However, the following requirements do apply:

- Persons generally cannot legally blend used oil with crude oil, product oil, or wastes to achieve "recycled oil" specifications (Section 25250.1 (c) and (d), HSC), unless blending occurs after "recycled oil" standards are met and at a facility permitted by the DHS to do so (Section 25201, HSC; Section 66300 (a) (2), CCR; and DHS policy).
- A generator of used oil who claims that his or her used oil meets the "recycled oil" standards and criteria must:
 - Notify the DHS of that claim (Section 25250.1 (e), HSC);
 - Comply with the following requirements for testing and recordkeeping (Sections 25250.1 (c)-(e) and 25250.19, HSC):

Ensure that the used oil has been tested and conforms to the standards and criteria for "recycled oil" designation;

Maintain a certification form to show that the used oil conforms to the standards and criteria for "recycled oil" designation; and

Maintain for three years records of tests performed and certification forms issued.

- Be able to prove to the DHS' satisfaction that the used oil meets "recycled oil" specifications (Section 25250.1 (e), HSC).
- A transporter of "recycled oil" and/or used oil that meets "recycled oil" specifications must maintain with each shipment of such oil (Section 25250.18, HSC):
 - The identity of the shipment's destination; and
 - A completed certification form obtained from the recycler or the generator certifying that the oil being transported meets "recycled oil" specifications.
- A facility owner or operator who recycles used oil to produce an oil which meets "recycled oil" specifications must do the following with respect to the recycled oil product (Section 25250.19, HSC):
 - Ensure that the recycled oil has been tested and conforms to the standards and criteria for "recycled oil" designation;
 - Maintain a certification form to show that the shipment of recycled oil conforms to the standards and criteria for "recycled oil" designation; and
 - Maintain for three years records of tests performed and certification forms issued.

Persons who handle used oil as described below are exempt from the requirements specified below with respect to that used oil (regardless whether the used oil meets "recycled oil" specifications):

- Persons who handle or manage used oil in conformance with one or more of the exemptions for recyclable materials set forth in Section 25143.2 (b), HSC, are exempt from the DHS' hazardous waste control requirements provided that none of the exclusions in Section 25143.2 (c), HSC supersedes, as specified (Appendix E).
- Persons who transport used oil to a permit-exempt facility, as described in the following paragraph, are exempt from DHS' hauler registration, vehicle certification, and manifest requirements (Section 25250.11 (b), HSC) if:
 - Each shipment transported does not exceed 20 gallons;

- Each container in each shipment does not exceed 5 gallons; and
- The transporter had used the used oil.
- Persons who receive used oil from consumers or other generators are exempt from DHS' facility permit requirements (Section 25250.11 (a), HSC) if:
 - Each shipment received does not exceed 20 gallons;
 - Each container in each shipment does not exceed 5 gallons; and
 - No other hazardous wastes are received there.
- Persons who operate refuse removal vehicles or curbside collection vehicles to collect and/or transport used oil from households, are exempt from DHS' hauler registration, vehicle certification, and manifest requirements and from other specified requirements (Section 25250.15, HSC).

The preceding paragraphs listed some of the specific requirements for used oil and/or recycled oil generators, transporters, and facility operators under SB 86 (1986) and related state hazardous waste control laws and regulations. For more detailed information, consult the text of SB 86 (1986) in Appendix D of this document and the other applicable laws and regulations cited in the second paragraph on page 11.

California Waste Management Board Requirements

The California Waste Management Board (CWMB) has limited responsibilities under SB 86 (1986) regarding the management of used oil. These appear in Section 3460 et seq., Public Resources Code (PRC) and include the following:

- The CWMB must prescribe guidelines for providing safe and conveniently located facilities for persons to deposit small quantities of used oil at no cost to those persons (Section 3466, PRC).
- The CWMB may request, review, and audit specified records regarding used oil from used-oil haulers, transfer facility operators, or recyclers (Section 3468, PRC).
- The CWMB must prepare and submit to the California Legislature an annual report which (Section 3470 (c), PRC):
 - Summarizes information on used oil collection and recycling;
 - Analyzes the effectiveness of rules and regulations; and
 - Recommends necessary changes in those rules and regulations.

5.1.2 Federal Statutory/Regulatory Requirements

Federal hazardous waste control laws appear chiefly in Subtitle C of the Resource Conservation and Recovery Act of 1976, as amended (Section 6901 et seq., Title 42, United States Code). Federal hazardous waste control regulations appear primarily in Parts 260-270, Chapter 1, Title 40, Code of Federal Regulations (CFR). The U.S. Environmental Protection Agency is the principal federal agency responsible for implementing federal hazardous waste control laws and regulations. For information about obtaining copies of the current federal hazardous waste control laws and regulations administered by EPA, contact the U.S. Government Printing Office Bookstore nearest you. The Bookstore in San Francisco can be contacted at (415)556-6657.

The federal laws and regulations applicable to the management of used oil are generally less stringent than the corresponding California laws and regulations discussed above. Therefore, the federal laws and regulations usually do not apply to the management of used oil in the state. However, there are some federal laws and regulations that should be discussed here for contrast with state laws and regulations. These federal laws and regulations can be summarized as follows:

- EPA does not list "used oil" or "waste oil" as hazardous waste.
- EPA conditionally regulates used oil as hazardous waste if it meets one or more of EPA's characteristics of hazardous wastes. The oil is hazardous if it is toxic, ignitable, corrosive, and/or reactive (Section 261.6 (a) (2) (iii), CFR).
- EPA exempts from regulation as hazardous waste characteristically-hazardous used oil, if it is recycled by some method other than burning for energy recovery (Section 261.6 (a) (3) (iii), CFR).
- EPA also exempts from regulation as hazardous waste a number of recyclable materials related to used oil and listed in Section 261.6 (a) (3), CFR. Most of these exempt materials are associated with oil-refinery operations.
- EPA regulates characteristically-hazardous used oil which is recycled by burning for energy recovery in boilers or industrial furnaces (as defined) that are not incinerators (Section 261.6 (a) (2) (iii), CFR), as follows:
 - If the oil meets EPA's specifications, then the used oil is essentially on-specification "used oil fuel" and is subject only to analysis and recordkeeping requirements. The requirements are comparable to those for "recycled oil" under California state laws and regulations (Section 266.40 (e), CFR). With two exceptions, EPA's specification requirements for origination as on-specification "used oil fuel" are the same as those for designation as "recycled oil" under California state laws and regulations.

- If the oil does not meet EPA's specifications, then the used oil is "off-specification used oil fuel" (Section 266.40 (e), CFR) and is subject to limited federal regulations for marketers and burners of such oil, as defined. For example, generators and transporters of "off-specification used oil fuels" are generally exempt from EPA regulation, as specified (Section 266.40 et seq., CFR). Also, under federal regulation, permits are presently not required of burners of "off-specification used oil fuel", although changes to this exemption have been proposed by EPA.
- EPA regulates characteristically-hazardous used oil which either is destined for disposal or for burning in incinerators essentially as fully-regulated, characteristically-hazardous wastes. This applies to incinerators that do not qualify as boilers or industrial furnaces, as defined. This means that hazardous waste facility permits are required for such incinerators and for disposal facilities.
- EPA does not require transporters of used oil or other hazardous wastes to register with EPA or to have their vehicles certified by any federal agency. EPA does require transporters to notify EPA.
- EPA presumes that used oil, which is destined for burning for energy recovery and which contains more than 1000 ppm total halogens, has been mixed with hazardous waste. That presumption is rebuttable, as specified (Section 266.40 (c), CFR). Such used oil is regulated under EPA's more stringent requirements for hazardous waste fuels. For example, generators and transporters of hazardous waste fuels are fully regulated as if they were generators and transporters of hazardous wastes (Sections 266.40 (c) and 266.30 et seq., CFR).

The preceding paragraphs identified some of the provisions applicable to used oil management under federal laws and regulations administered by EPA. For further information, consult the appropriate federal laws and regulations cited in the first paragraph of this subsection.

5.2 Federal and California Water Quality Guidelines

This overview is limited to the regulations that pertain to the management of oil wastes.

5.2.1 Regulatory Agencies

Through authority established by the Clean Water Act and the Safe Drinking Water Act, EPA administers water quality control programs for wastewater disposed to surface waters, municipal sewers, and injection wells. In California, surface water disposal is regulated by the National Pollutant Discharge Elimination System (NPDES) program. Administration of the program has been delegated to the state. The state also recently applied for delegation of the Pretreatment Program which regulates the discharge of industrial wastewaters into municipal sewer systems. The Underground Injection Control (UIC) program, which regulates wastewater disposal in

injection wells, is administered by EPA, with the exception of oil production-related injection wells, which are regulated by the California Department of Conservation, Division of Oil and Gas.

Through authority provided by the Porter-Cologne Water Quality Control Act and other state legislation, nine Regional Water Quality Control Boards administer water quality control programs in their geographic areas. Regional Water Quality Control Boards possess the authority to regulate discharges to surface waters, land (including surface impoundments), municipal sewers, and injection wells. Statewide oversight is provided by the State Water Resources Control Board.

The Regional Water Quality Control Boards adopt waste discharge requirements to protect the waters of the state for the use and enjoyment of the people of California. Any questions regarding wastewater discharge regulations should be directed to the nearest office of the California Regional Water Quality Control Boards (Appendix G).

Additional discussion on the requirements for the disposal options is provided below.

5.2.2 Surface Waters

Under the Clean Water Act and NPDES regulations, EPA issues technology-based effluent limitations on wastewater discharges to surface waters based on industrial category. California incorporated these guidelines in the regulations implemented by the Regional Water Quality Control Boards. The guidelines and standards are based on chemical use minimization or substitution, and water use reduction to reduce pollutant discharges. The Regional Water Quality Control Boards may adopt more stringent limitations to protect the water quality of specific receiving waters. The specific limitations for any facility are incorporated into an NPDES permit issued by the Regional Water Quality Control Boards.

Generally, the limitations are expressed in terms of constituent limits placed on the wastestream. Two limits apply: a one-day maximum, and a monthly average.

5.2.3 Above-Ground Storage Tanks

The Regional Water Quality Control Boards also possess the authority to require industries to develop Best Management Practice (BMP) plans to prevent or mitigate water pollution from sources ancillary to industrial manufacturing or treatment processes. BMP plans may contain provisions for good housekeeping, employee training, preventive maintenance, security, and physical improvements such as alarms or containment structures around storage tanks.

5.2.4 Land

For facilities disposing of wastewater to land, the Regional Water Quality Control Boards develop effluent limitations which are incorporated into water discharge requirements. These limitations are developed in accordance with California Code of Regulations, Title 23, Chapter 3, Subchapter 15, Discharge of Waste to Land.

Industries that store, treat, or dispose of liquid hazardous wastes in surface impoundments are also subject to the provisions of the Toxic Pits Cleanup Act of 1984.

5.2.5 Municipal Sewer

Chapter 11.1 provides a Pretreatment Regulatory Review for municipal sewer systems.

5.2.6 Injection Wells

Industries that dispose wastewater to injection wells are regulated by the Underground Injection Control (UIC) Program administered by EPA. Specific injection well operators are issued UIC permits by EPA. In addition, the Regional Boards have the option of issuing waste discharge requirements to injection well owners and operators.

5.2.7 Underground Storage Tanks

Recently passed federal and state legislation protects the waters of the state from discharges of hazardous substances from underground storage tanks. State regulations establish tank construction, monitoring, closure, and reporting requirements. Counties are required to implement the regulations. In some cases, cities can assume the responsibilities within their boundaries.

5.3 Air Quality Regulations

5.3.1 Federal Requirements

The federal air quality permit program is administered by EPA. The program established health-based ambient air quality standards (AAQS) for major air pollutants. The program is concerned primarily with those pollutants for which the national ambient air quality standards (NAAQS) are being attained. These pollutants are called "attainment" pollutants. Permits are required for new or modified sources of air pollution if one or more attainment pollutants are emitted in amounts above specified levels. Thus, a company adding a piece of equipment to their process would need a federal air permit if an attainment pollutant were emitted in amounts greater than specified "significant levels" defined in the regulations. The permit is called a "prevention of significant deterioration" (PSD) permit. Several California air pollution control districts have recently received authorization from EPA to administer the PSD program in their districts.

Some oil waste management equipment discussed in the Guide emit volatile organic compounds (VOCs). VOCs are precursors to the pollutant ozone. Ozone is a non-attainment pollutant in many areas of California. Therefore, a PSD permit may be necessary for a facility that vents emissions.

A pollutant is defined as a "non-attainment" pollutant if the NAAQS are being violated for that pollutant. Non-attainment pollutants come under the jurisdiction of California's air quality regulations discussed below.

5.3.2 California Requirements

California also has set air quality standards for major air pollutants. Some of these standards are more stringent than the NAAQS. For a proposed facility to receive an air quality permit in California, the applicant must show that the project will not interfere with achieving or maintaining the state and national AAQS.

Permits are required for any piece of equipment or process that emits air contaminants unless it is specifically exempted. A more vigorous permitting process is applied to major sources, as defined by air pollution control district and EPA regulations.

Sources that plan to locate in an area that is non-attainment for an AAQS must apply for New Source Review (NSR) permit. This program is administered by the local air pollution control district with oversight by the California Air Resources Board (ARB). NSR requirements vary by air pollution control district but follow some general guidelines. The air pollution control district in which a facility is to be located should be contacted early in the planning stage to determine the specific requirements. A list of California air pollution control districts is in Appendix F.

One major component of the NSR program requires proposed facilities emitting non-attainment pollutants, or their precursors as defined in regulations, to apply best available control technology (BACT). NSR also requires emission offsets if the projected emissions are above the "trigger" levels. The air pollution control districts "discount" the offsets to cause a net improvement in air quality.

The purpose of the offsets is not only to negate the new facility impact on an AAQS violation, but to actually improve the ambient concentration and progress toward attaining AAQS. Also, facility emissions must sometimes be analyzed by atmospheric dispersion modeling to determine impacts on attaining state and national AAQS.

New facility projects must also comply with California's toxic air contaminant program. Under this program, the ARB identifies toxic air contaminants. The ARB and APCD develop control programs for the contaminants. The APCDs will administer the control programs.

Some common industrial solvents may occur in oil waste. These have already been identified as toxic air contaminants. These solvents include benzene, ethylene dibromide, and ethylene dichloride. More solvents are currently being identified.

Control programs developed for toxic air contaminants will probably be applied at emission levels much lower than the typical 150 lb/day trigger level for the NSR program. In addition, siting decisions for sources of toxic air contaminants may involve risk assessment based on atmospheric dispersion modeling.

5.4 Further information

The above summaries of state and federal laws and regulations are not exhaustive. To obtain additional information about various aspects of the management of used oil and other hazardous wastes, contact the appropriate organization listed in Appendix F or Appendix G.

CHAPTER 6 ONSITE MANAGEMENT TECHNIQUES

6.1 Source Reduction

The most effective way to reduce or eliminate used oil disposal problems is to eliminate the source. This ideal is generally difficult to achieve, but by careful evaluation of production and process operations, some improvements are possible. The following sections discuss the nature of oils used in industry and ways to reduce used oil generation.

6.1.1 Types of Oils Used

A wide variety of oils are used in machinery, equipment and engines. They are used for lubrication, as operating fluids and process oils. While these oils may be classified in a few simple categories, there are actually thousands of different oils used. The large number of oils is due to the different formulations and suppliers, and due to manufacturers of equipment and machinery who specify a specific oil to be used in their unit. For example, a manufacturer may specify a certain lube oil, but this product may be supplied by twenty or thirty lube oil producers. Each product may have different additives and compositions. Thus, a wide diversity of lubricating oil properties and many brands and grades are available. Chapter 4 has detailed information about oil types, their use, and resulting waste.

The major categories of used oils generated in California and percent of total oils are given in Table 6-1 (1), excluding fuels.

Used oils are produced mainly from equipment drainings during maintenance and overhaul operations. Some used oils are also generated from over-age stocks, and from contamination in transport or storage.

The total volume of used oils generated in the US has been estimated from 1,205 million (2) to over 2,300 million (3) gallons per year. The volumes reported for California are 100-130 million gallons per year (1,2,4). Details of the composition and components of various virgin and used oils have been provided in Chapter 4 above and extensively reported elsewhere (2,3, 5-11).

6.1.2 Use of Water Soluble Oils/Detergent Systems

Most of the oils described in Section 6.1.1 are used in machinery and engines. These devices usually operate at high speeds or heavy loads, and at extreme temperatures. These oils are intended to reduce friction, prevent wear or corrosion, and carry the loads needed to keep the machines operating at maximum efficiency. In effect, the oil becomes an integral part of the machine. Use of water soluble oils or water-based systems has some merit in special cases. However, due to the often severe requirements of machinery, the opportunities for oil substitution are limited.

Some cutting oils are water soluble. They are used in cutting machines to provide cooling and a small amount of lubrication. Such oils are formulated with detergents. Concentrations are about 1-3 percent oil in water. Use of

Table 6-1. Types and volumes of used oils available for recycling in California (1984 values).

Oil Type	Volumes of Used Oils	
	Millions of G/Yr	Percent of Total
Automotive Uses		
Lubes	66.574	51.6
Hydraulic & Transmission	11.83	9.2
Subtotal	78.404	60.8
Industrial Uses		
Process	16.736	13.0
Hydraulic	11.744	9.1
Metalworking	4.829	3.7
Railroad	3.368	2.6
Marine	2.419	1.9
Turbine	2.279	1.8
Gear	2.032	1.6
Other	7.071	5.5
Subtotal	50.478	39.2
Total	128.882	100.0

this type of oil should be maximized for cutting and cooling operations. Most equipment suppliers of cutting machines also provide units to purify and recycle emulsified oils. This extends their useful life.

Another water-based formulation is fire resistant hydraulic fluid. These formulations contain emulsified oils with 60-95 percent water. These products have limited service temperature requirements. Many fire resistant hydraulic fluids are organic phosphates which may be difficult to manage. Often water-based formulations can be excellent alternatives.

Oils and solvents are used extensively as the base for inks. Recently, ink manufacturers have been changing to water-based inks, thus eliminating generation of used oils. This appears to be a simple change. However, it can involve extensive changes in equipment and process operations. This may require considerable capital investment.

6.1.3 Substitution

Substitution of oils by water-based compounds has been discussed in the previous section. Other replacement options include the following:

- By proper management of inventories and handling, storage periods for component parts can be reduced or eliminated so that the oil-based preservatives are no longer needed. Thus, the need to remove and dispose of this oil can be drastically reduced.
- In some cases, process oils such as roll oils can be eliminated by altering metal composition, metal handling, machine design or operating procedures.
- Hydrocarbon-based transformer oils generally contain various quantities of PCBs as stabilizers. These oil formulations are being replaced by non-hydrocarbon liquids such as silicones and freon-based liquids.

6.1.4 Extended Life Oils

Most oils in current usage are hydrocarbons derived from petroleum. In service, these oils tend to oxidize and may also degrade to lower molecular weight, more volatile components. When these degradation products reach a certain critical level, the oils need to be replaced or recycled. For many applications, such as engine and turbine oils, life can be extended by changing to non-hydrocarbon oils:

- Aviation Turbine Lubes - These lubricants consist of di, tri and polyesters synthesized from organic acids and alcohols. Aviation turbine lubes are almost exclusively composed of such materials. Compared to hydrocarbon oils, they provide considerably longer service.
- Automotive Lubes - Synthetic oils are also widely marketed as automotive lubes, such as Mobil I. These oils have the following advantages:

- Less oxidization occurs in service. Therefore less sludge and oxidized by-products are generated.
- Synthetic oils can hold greater amounts of additives which tie up carbon particles and other combustion products. This provides longer service life.

A major disadvantage of such oils is their high cost and the fact that many engine manufacturers require oil changes at specific mileage intervals. These intervals are often much below the service life of synthetic lubricants. As a result, the benefits of synthetic lubes cannot be realized without jeopardizing the warranty requirements.

- Fire-Safe Hydraulic Fluids - As noted above, some fire-safe hydraulic fluids can be formulated as water-based materials containing 5-30 percent hydrocarbon oil. By substituting the hydrocarbon portion with synthetic oils, the life of these fire-safe hydraulic fluids can be extended.

6.1.5 Reformulation of Oils

Additives used in oils often contribute significantly to the toxicity of used oils. The types of additives commonly used are noted in Table 6-2 (5,12). Many oil formulators are making efforts to reduce or eliminate toxic additives. For example, PCBs are no longer being used as stabilizers for electrical insulating oils. This is because of problems caused by disposal of these toxic substances.

Other major toxic substances used are metal salts of various organic and phosphoric acids, phenolic and halogenated compounds. Industrial users of oils should require suppliers to change formulations to minimize or eliminate use of toxic additives.

6.1.6 Biodegradable Oils

Biodegradation of organic materials is a natural process that has been practiced on a broad range of substances. Naturally occurring bacteria and microorganisms can decompose almost any organic. Most organisms are ubiquitous. For biodegradation of used oils, it is necessary to define the rates of decomposition of the specific wastes. It must also be determined how to maximize their rate of degradation. Extensive studies on petroleum products have shown that both land-based and water-borne organisms can biodegrade these materials in as little as 1-6 months. The decomposition products are humic acids which generally are beneficial to most soils.

To maximize biodegradability of oils, it may be necessary to reformulate products to eliminate or reduce components which can inhibit biodegradation. For example, phenolic compounds and certain heavy metals are toxic to microorganisms. Thus, if biodegradation is to be used as a disposal method, industrial users should request products without these substances.

It should be noted that biodegradation is not a panacea for all types of oils or other wastes. However, the potential for this method has not been

TABLE 6-2. COMPOSITION, APPLICATION AND FUNCTION OF LUBRICATING OIL ADDITIVES

Name of Additive	Composition	Application	Function
Corrosion Inhibitor	Zn and Ba dithiophosphates, dithiocarbamates, metal sulfonates, and sulfurized terpenes	IC engines, alloy bearings, ATF	To react with metal surfaces to form a corrosion-resistant film
Rust Inhibitor	Sulfonates, alkylamines, amine phosphates, alkenylsuccinic acids, fatty acids, and acid phosphate esters	IC engines, turbines, electric and mechanical rotary machinery, fire-resistant hydraulic fluids	To react chemically with steel surfaces to form an impervious film
Antiodorant	Perfumes, formaldehyde compounds	With EP additives	To mask odors
Antiseptic	Alcohols, phenols, chlorine compounds	With water added to oil emulsions	To inhibit microorganisms
Antioxidant	Sulfides, phosphites, amines, phenols, dithiophosphates	IC engines, turbines, and rotary machinery	To inhibit oxidation of oil
Antifoam	Silicones, synthetic polymers, waxes	Same as rust inhibitors, excluding ball bearings	To permit air bubbles to separate from oil
Detergent	Sulfonates, phosphonates, phenates, alkyl substituted salicylates combined with barium, magnesium, zinc and calcium	IC engines under steady load	To neutralize acids in crankcase oils to form compounds suspended in oil
Dispersant	Alkenyl succinimides, alkyl-acrylic polymers, ashless compounds	IC engines at low temperatures and variable loads	To disperse contaminants in the lubricant

Abbreviations: IC = Internal Combustion Engine; ATF = Automatic Transmission Fluid; EP = Extreme Pressure

TABLE 6-2. (Continued)

<u>Name of Additive</u>	<u>Composition</u>	<u>Application</u>	<u>Function</u>
Metal Deactivator	Organic dihydroxyphosphines, phosphites, and sulfur compounds	IC engines, turbines, electric motors, air compressors, hydraulic oils	To form protective film on running surfaces to inhibit corrosion reactions
Color Stabilizer	Amine compounds	When heat and oxidation darken oil	To stabilize oil color
Viscosity Index Improver	Isobutylene polymers and acrylate copolymers	IC engines, electric motors, air compressors, hydraulic oils	To retard loss of viscosity at high temperatures
Pour Point Depressant	Polymethacrylates, polyacrylamides, alkylated naphthalenes and phenols	IC engines, gears, bearings, transmissions	To prevent congealing of oil at low temperatures
Extreme Pressure Additives	Organic compounds with sulfur, phosphorous, nitrogen, halogens, carboxyl or carboxalate salt	IC engines, turbines, motors hydraulic oils, gears, rollers and ball bearings	To form low-shear-strength film providing lubrication at startup and at high bearing loads
Antivear Additive	Chlorinated waxes, organic phosphates, lead naphthenate	As above	As above except for running condition
Tackiness Agent	Polyacrylates and polybutenes	Gear enclosures from which oil must not drop	To improve adhesive qualities of base oil
Emulsifier	Surfactants, sulfonates, naphthenates and fatty acid soaps	Soluble cutting oils	To reduce interfacial tension and permit formation of water-oil emulsion

Abbreviations: IC = Internal Combustion Engine; ATF = Automatic Transmission Fluid; EP = Extreme Pressure

fully utilized. Research is needed to define optimum conditions for various substances.

6.1.7 Good Housekeeping

Good management of oil products includes housekeeping practices to reduce generation of used oils that are difficult or costly to manage. Several examples are noted below.

- Volume Reduction - Oily wastes such as refinery sludges often contain large amounts of water. Dewatering by centrifuging or filtering can reduce the volume by 40-60 percent (13). The separated oily sludge may be returned to the refinery when appropriate. The water phase may be suitable for reuse.
- Inventory Control - Proper monitoring of inventory can reduce accumulation of overaged oil products. These products may be returned to the supplier for upgrading. Also, standard practice should include testing products received to assure their quality. This can avoid potential contamination in subsequent operations.
- Eliminate Contamination - Proper labelling, handling and overall management can significantly reduce mixing errors and resulting contamination. For example, oil formulators need to take extreme care not to contaminate products in mixing tanks, in storage tanks and handling operations. Use of clean tanks and vessels can avoid unwanted contamination. Proper control valves and system designs are needed to eliminate possibilities for contamination.
- Spill Avoidance - Careful handling procedures, use of proper equipment and training, can result in a large reduction in spillage. In addition, contingency planning can minimize the severity of spills. It can also reduce volumes of contaminated oils needing disposal.

6.1.8 Training

Source reduction and other good management practices require personnel training. Most oil users do not fully appreciate source reduction opportunities. Once changes have been recommended, personnel need to be taught the purpose of such changes and how to implement them. Training needs to be done by someone knowledgeable in plant operations, product usage, and waste management. Experience has shown that without adequate training, it is often impossible to change habits and past practices. Training should include:

- Problem definition
- Reasons for changes
- Description of desired practices
- Specifics of new practices, including hands-on experience

- Management support and resources
- Incentives for change
- Follow-up to assure acceptance

6.1.9 Recommendations - Generator Needs

In order for generators of used oil to realize the full potential of source reduction practices, a site specific audit is needed. This audit should accomplish the following:

- Identify the quality and quantity of oils used
- Identify the quality and quantity of used oils generated
- Identify the sources of used oils
- Identify current waste management practices
- Identify options available for source reduction
- Economic and feasibility studies of various options
- Selection of the most cost-effective and environmentally preferred option
- Detailed instructions and costs for implementation of recommended practices

If the generator has an operation such as a service station or auto repair shop, an audit can be quite routine. For more complicated industrial operations, the audit needs to be extensive enough to identify and solve the problems. The latter may involve detailed studies of plant operations and processes which most likely would include other waste materials. DHS has available a series of industry specific waste reduction audit manuals for small quantity hazardous waste generators.

6.2 Contaminant Control

The most important aspect of contaminant control is to prevent cross-contamination. This involves careful segregation of waste oil streams to prevent introduction of heavy metals, solvents, halogenated organics, or radioactivity into recyclable streams. Contaminants can make processing of the mixed stream much more difficult and expensive. A mixed stream may be a much larger, more dilute stream that must be processed in a more expensive way. The following sections will discuss contamination and contaminant removal in more detail.

6.2.1 Heavy Metals

The heavy metals frequently found in waste oils are usually products of wear, combustion, or additive. Table 6-3 gives typical metal concentrations

found in waste oil (5). It also has EPA and California permissible levels for unrestricted burning.

Cadmium and chromium generally come from wear. Barium and zinc come from lube oil additives. Lead comes from leaded gasoline by engine blowby. The source of arsenic is unknown.

Discussions with used oil processors indicate that lead levels are declining. For 1987, lead levels for used automotive engine lubricants are more nearly 200 ppm. This is due to reductions in lead level in gasoline.

6.2.2 Volatile Organics (Solvents)

Oxygenated and aromatic solvents in used oil come from cross-contamination with spent solvents. Light hydrocarbon contamination comes from fuel blow-by in the engine, and from use of fuel as a solvent. These materials are readily removed by distillation at atmospheric pressure or under mild vacuum. The recovered distillate can usually be used as fuel in a rerefining operation. However, it has too low a flash point to be marketed as an on-spec fuel.

6.2.3 Halogenated Solvents

Chlorinated solvents are a major used oil contaminant. They are usually introduced through careless or ignorant management practices by generators or transporters. The usual contaminants are degreasing solvents such as tetrachloroethylene, trichloroethylene, 1,1,1-trichloromethane, trichlorotrifluoroethane, and dichlorodifluoromethane. They usually get into the used oil by auto mechanics disposing of small amounts into the used oil tank. They are detected by measuring total chlorine. Some chlorine can be present in innocuous forms such as inorganic salts. However, chlorine content is an indicator of possible contamination of the used oil by potentially hazardous chlorinated materials. Thus chlorine content is a very useful measurement. Typical chlorine concentrations in used oils vary from 1,000 to 5,000 ppm. Since most chlorine compounds are introduced into used oil by carelessness, careful segregation practices can overcome this problem.

6.2.4 PCBs

While PCBs were found in only one third of the samples measured in the 1983 study, one quarter of the samples analyzed may have had concentrations above 15 ppm. These concentrations probably came from blending PCB-stabilized oils into the used oil tank. In the past, PCBs were used to stabilize electrical transformer oils and heat transfer oils. This extended their life in the face of thermal or oxidative free radical reactions. Concern about the toxicity of PCBs caused their use in such oils to be curtailed. Recently, there has been a sharp reduction in the occurrence of PCBs in used oil. Used oil processors in California say that PCBs are not much of a problem for them. Just as with chlorinated solvents, contamination with PCBs comes from failure to segregate streams containing PCBs. This again points out the importance of knowing what is in the oily wastes that one generates or collects. Increasingly, rerefiners are sampling used oil

Table 6-3. Typical metal concentrations in waste oils and maximum levels for unrestricted burning.

Metal	Typical level, ppm		Maximum level allowed, ppm	
	Mean	Median	California CCR Title 22	U.S. EPA
Arsenic	17	5	5	5
Barium	132	48	100	NA
Cadmium	3	3	2	2
Chromium	28	7	10	10
Lead	665	240	50	100
Zinc	580	480	250	NA

NA means no standards have been set for barium and zinc.

The values in the above table are mean and median concentrations for 1,071 used oil samples reported for 1983.

pickups. This helps avoid blending of halogenated materials into uncontaminated used oils.

6.2.5 Radioactivity

Unlike most used oil contaminants, radioactive materials cannot be converted into innocuous substances. Radioactivity decays according to the half-lives of the radioactive elements. Diluting the waste with non-radioactive materials will merely make more material contaminated with radioactivity. Thus, extremely careful segregation is needed for radioactive oils. Generators include mainly operators of nuclear power plants and users of radioisotopes. Radioactive debris must be kept out of waste oil streams. It must be handled according to the rules of the Nuclear Regulatory Commission.

6.2.6 Trends in Control

Increasing regulatory constraints, advancing technology, and declining land disposal capacity are all affecting waste management economics. There is increasing need to recycle used oil into on-spec fuel or rerefine it for its original use. Reprocessing and rerefining technology which generates hazardous streams requiring landfill disposal will be at a disadvantage. Thus, recycling processes generating hazardous sludges or requiring large amounts of clay or other adsorbents will be at a disadvantage. Chemical treatment will be at a growing disadvantage compared to distillation and hydrotreating for reclaiming used oils.

6.2.7 Conclusions

To insure contaminant control, a generator must know what is in the various streams he generates. He must also know how to segregate these waste streams to prevent cross contamination. Some used oil transporters and reprocessors train their customers to properly label collection drums. Personnel must be trained to segregate properly. Some transporters have adequate analytical facilities to determine what hazards are in the generator's waste streams. Reprocessing will grow as a viable business. Uniformity in the quality of recycled product will improve. Awareness of the value of used oil as a resource will increase. A larger, steady supply of used oil feedstock will improve the economies of scale and profitability of used oil recycling.

6.3 Mixing Used Oils

Guidelines for mixing of used oils are a function of the oils available and the desired waste management options. Suggestions for segregation and compatible groupings are given below.

6.3.1 Types of Oils Used

Section 6.1.1 covered the types of oils used in industry. Oils included in this study are those with flash points above 100 °F. Lower flash point hydrocarbons such as naphtha, benzene, toluene, and heptane are classified herein as solvents. Oils in this study include:

- Oils with flash points Between 100-130 °F - This category includes mineral spirits. These are used mainly as solvents, but also as light lubricating oils for some applications. Others are Jet A aviation fuel, diesel fuel and kerosene. These oils can generally be segregated and recycled to meet original product specifications. While these oils are blended into fuels, many users prefer fuels with a flash point above 130 °F. Used oil processors can blend these materials and distill off the light fractions to increase the flash point.
- Oils with flash points above 130 °F - Most used oils and fuels such as JP-5 military aviation fuel, #2, 4, 5, 6 and other residual fuels, fit into this category.
- Oil/Water Mixtures - Certain oil/water emulsions or mixtures can be blended into fuels, provided they do not cause excessive quality degradation. Residual fuel specifications allow from 1-2 percent water and sediment.
- Oils Containing Materials with a flash point Below 130 °F and halogenated solvents - Generally not acceptable for recycling with used oils.

6.3.2 Segregation

Segregation is often required for the recycling options below:

- Recycling for the Original Use - To reclaim a lube, hydraulic, turbine or other oil for its original purpose, the used oil must be kept segregated. Blending with other oils alters the specifications, and treatment methods noted in Section 8.1 are not adequate to remove contaminants. Even if the oil is returned to the supplier for reclamation, he wants material as pure as possible.
- Recycling for Plasticizer or Other Specific Usage - Downgrading used synthetic oils for use as a plasticizer requires segregation to minimize contamination.

6.3.3 Compatible Mixing

Compatible mixing depends upon the recycling option to be implemented. Careful mixing can maximize recycling cost-effectiveness. Guidelines for mixing used oils are given in Table 6-4.

As indicated above, recycling for the original purpose or for plasticizer use requires strict segregation. For fuel usage or blending into asphalt, most used oils can be mixed together. Exceptions are those containing halogens or materials with a flash point below 130 °F. Since all the oils noted in Table 6-4 have fuel value and are chemically compatible, they can be mixed together. If the used oil has high water percentage, care needs to be taken to assure that the blended fuel meets water limitations.

Table 6-4. Guidelines for grouping oils for several recycling options.

Used Oil Type*	Recycling Option		
	Rerefining for Original Use	Plasticizer	Fuel or Asphalt
Automotive (Gasoline/Diesel)			
Lube	Keep Separate	Not Applicable	Can Mix
Hydraulic	"	"	"
Transmission	"	"	"
Industrial			
Process	"	"	"
Hydraulic	"	"	"
Metalworking**	"	"	"
Railroad	"	"	"
Marine	"	"	"
Turbine	"	"	"
Gear	"	"	"
Synthetic			
Lube	"	Keep Separate	"
Hydraulic	"	"	"
Turbine	"	"	"
Fuels			
Flash Point above 130 °F	"	Not Applicable	"
Flash Point 100-130 °F	"	"	Cannot Mix
Mixture Containing Halogens or Materials with Flash Point <100 °F	"	"	"

* All oils are hydrocarbons except where indicated

** For fuel use, end blend must contain less than 1-2 percent water

Table 6-4 is a guideline. Except for fuels, many of the used oils listed therein may not be recyclable for original use in California. This is because offsite services are not readily accessible or available. Infrequent generation, low virgin replacement cost, and convenience may also disfavor recycling for original use. The generator should be observant for future opportunity and attractiveness of this waste management option.

6.3.4 Training

Training is essential for proper segregation and mixing. The trainer needs to understand oil usage, properties and planned recycle methods. Trained personnel must have incentives, equipment and knowledge of practices required to implement successful programs. Training should include:

- Identification of all used oils
- How materials should be labelled and the means to do so
- Designation of collection locations and containers
- Instructions on what can and cannot be mixed
- Detailed instructions on how to carry out the required operations and hands-on experience
- Incentives for changes
- Management support and resources
- Assistance in compliance and follow-up

6.3.5 Recommendations

To assure proper segregation and mixing, the following recommendations are provided for generators and transporters:

- Identify the quality and quantity of oils
- Determine where used oils are generated, and by which personnel and operations
- Identify current management practices
- Select the best management option
- Plan used oils storage and transportation
- Train personnel
- Provide proper equipment and facilities
- Implement the program

- Closely monitor activities to assure that the program works properly. Provide changes as needed.

6.3.6 Illegal Practices

Illegal practices for used oil management include the following:

- Blending with virgin oil to meet used oils specifications
- Comingling oil waste with other hazardous waste
- Road oiling
- Use in or disposal to non-permitted facilities
- Land disposal
- Disposal into the sewer
- Disposal with household or industrial refuse

6.4 Onsite Reuse Practices

Onsite reuse of used automotive oils normally falls into four categories: (1) burning directly in space heaters; (2) burning as a diesel fuel-used oil mixture in vehicle engines; (3) road oiling for dust control; and (4) mixing with fuel oil for burning in onsite boilers. However, California regulations prohibit burning used oil in space heaters, road oiling with used oil, and mixing with virgin fuel oil for burning. Burning a diesel fuel-used oil mixture in vehicle engines is also illegal.

A EPA study reported that 33,900 waste oil heaters were sold from 1979 to 1983. It is likely that a significant number of these heaters are owned by farmers, mining companies, or even individuals who are not used oil generators. Use of these space heaters is prohibited in California.

Some automotive used oil generators mix used oil with virgin diesel fuel for burning in vehicle engines. This activity is primarily limited to trucking fleets, the U.S. military services, and some large off-road vehicle operators. This practice is illegal in California.

Some large construction, mining, and forestry companies use accumulated used oils for dust control on private roads. This onsite reuse activity is illegal in California.

Used automotive oil is often used for onsite burning in conventional boilers, primarily by U.S. military bases. Several documents have reported that this activity may consume up to 50 percent of the used automotive oils generated by the Department of Defense. This practice is now regulated on both a federal and state level.

6.5 Management Practices That Improve Waste Stream Recyclability

Contaminant Reduction

Contaminants can enter into used oil in a number of ways. One is by the breakdown of additives. The other is poor housekeeping and management practices. Research into substitute lubricants may reveal oil formulations that perform the same function but do not break down due to chemical interaction as quickly. Employees training and proper procedures can minimize contamination.

Education of Generators

Generators who segregate their waste streams can reduce their disposal costs. Oil replacement based on contamination levels instead of time frequency can increase the life of equipment and reduce oil replacement costs. Generators can take the following measures to improve recyclability:

- Identify contaminants
- Fingerprint sources of contamination
- Establish procedures to eliminate waste sources
- Set up separate waste drums for solvents and antifreeze
- Check equipment regularly for leaks
- Determine effect of temperature, pressure, and other conditions on oil life

Inspection by Transporters

Transporters who test used oils for contamination by other hazardous wastes can improve the quality of oil which is collected. Used oil with low water and low hazardous contaminant content are more valuable to a reprocessor/rerefiner.

Waste Stream Segregation

Segregation of wastes allows the generator to choose the most economical waste management method. For example, water contaminated with oil could cost as much as \$3.00 per gallon to haul away for treatment or disposal. Used oil may only cost \$.15-.25 per gallon for recycling. Therefore, it is economical to keep wastes segregated.

6.6 References

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CHAPTER 7

EVALUATION OF USED OIL COLLECTION PROGRAMS

Used oil collection programs accumulate used oil from individuals and industrial sources for proper waste management. For individual generators, the majority of used oil collection programs are operated by nonprofit organizations, service stations, and local communities. Some programs are operated on a commercial scale. City and county government recycling programs are also operated.

7.1 Generator Considerations in Selecting a Program

The initial reason for a used oil generator to evaluate collection programs is need for responsible waste management. If options for reuse and onsite recycling are not viable for a generator, then the generator must find an acceptable alternative.

Economics a primary consideration in selecting a collection program. Generators want to minimize waste management costs, and excessive collection cost may promote uncontrolled disposal. Ideally, generators would be paid for their used oil. However, due to market conditions, regulations, and insurance costs transporters must usually charge a fee.

Convenience is another prime consideration. If a collection program picks up used oil directly from the generator, then the generator is spared time and effort. For large-quantity generators, a used oil collection service can provide truck transportation equipment and the manifests required for hazardous waste transportation.

It is important for generators to be aware of their options when selecting a program. Small-quantity generators may have available local collection stations in gas stations and auto repair shops, collection days offered by used oil recyclers, and city-operated curbside pickup services or hazardous waste collection days. Large-quantity generators may have available several recycler pickup services. They could also transport used oil to an industrial collection station themselves, but this would require that they be registered as hazardous waste haulers.

7.2 Description of Collection Programs

7.2.1 Collection Stations

Collection stations accept used oil brought in by generators. They are operated by gas stations, auto repair shops and other businesses that have tanks or drums for used oil storage. Collection stations are generally designed to accept oil from small-quantity generators. The majority of oil accepted by collection stations is crankcase oil brought in by do-it-yourselfers. Collection station oil typically consists of 90 percent crankcase oil, 3 to 5 percent water, and small amounts of transmission fluids, gear lubricants and hydraulic oils (1).

Collection stations are generally not end users or recyclers of used oil. They usually pay haulers to remove the oil. Haulers then transport the oil

to a recycler or to a location outside the state of California, where it can be recycled, reused or burned.

In the 1970s and early 1980s, when oil prices were high, collection stations were paid by oil recyclers for their used oil. Thus the stations were able to accept used oil with no surcharge to generators. As oil prices declined through the mid- and late-1980s, the value of used oil dropped. Collection stations then had to pay recyclers to accept the stations' used oil. Collection stations are now charged up to 25 cents per gallon by transporters to haul off the stations' used oil. Some collection stations still accept used oil from generators at no charge as a public service (e.g. K-Mart). Others charge from 25 cents to one dollar per gallon to offset their own costs. Other companies that once collected used oil now refuse to accept it due to escalating costs and liability issues.

7.2.2 Collection from Industrial Sources by Haulers and Recyclers

Many used oil recyclers collect used oil from industrial generators. Used oil from commercial engine fleets or railroad service centers is transported by truck to the recycling plant. There are also independent haulers that collect used oil from industrial sources, transport it, and sell it based on spot market economic conditions. Industrial generators accumulate used oil in large tanks or drums. Transporters come by on a regular schedule to pump oil out of the tanks and haul it away.

Independent transporters generally charge up to 25 cents per gallon to pick up used oil. Upon delivery to a recycling plant, transporters receive about 5 to 8 cents per gallon from the recyclers. Transporters deliver oil to recyclers as nearby as possible, because every 100 miles of highway transportation adds 5 cents per gallon to shipping costs (2). Independent collection and hauling programs have greatly decreased in number in recent years. Liability has caused insurance costs to increase dramatically. In addition, economies of scale favor large operations. Thus larger companies have remained in business while many smaller companies have shut down. The drop in crude oil price has been the economic factor most affecting transporters over the past few years.

Recyclers charge industrial generators to collect oil in a manner similar to independent haulers. Recyclers charge for oil collection to cover insurance and permit costs, as well as to preserve the profit margin on their recycled product. Recycled oil market conditions, cost of complying with regulations, and plant capital costs affect the price recyclers charge for oil collection.

7.2.3 Public Collection Programs

Public collection programs can be governmental or commercial. Commercial public collection programs usually establish a place and time for used oil collection. They are usually conducted by local recyclers and rerefiners. Programs are conducted in locations that are easily accessible to the public, such as parking lots of large shopping centers. Programs are publicized using posters and fliers. Commercial public used oil collection requires a significant allocation of manpower and equipment. Therefore,

these programs are generally not cost efficient. However, they provide publicity for recyclers, and help to enhance community relations.

Governmental collection programs can be either curbside pickup services or hazardous waste collection days. Curbside pickup services require that residents segregate their recyclable wastes. Categories include paper, aluminum, glass, and oil. The wastes are then taken to a recycling center. In areas where curbside programs exist, 10 percent of household generated used oil typically gets collected. Curbside waste pickup services have sound environmental principles. They are usually supported by city councils and the public. However, they are not cost efficient. Cost-to-revenue ratios run as high as 10 to 1 (3). Strong public support and publicity can result in a more successful program. A better alternative may be to have used oil picked up with other residential garbage. Homeowners would pay a surcharge to cover collection costs.

Hazardous waste collection days are government sponsored events. Sites are temporarily established for the public to bring in household hazardous wastes. These wastes include pesticides, insecticides, solvents, and used oils. Days are conducted on weekends at local public parks or shopping centers. These programs generally elicit good public response. They raise public awareness concerning hazardous waste management. However, due to manpower and equipment requirements and waste disposal costs, hazardous waste collection days are expensive. Costs range from 1 to 5 dollars per gallon of waste collected (3,4,5).

While public collection programs can be expensive to operate, the offset costs of disposal should also be considered:

- Cost to society to clean up contaminated land and water in the future
- Cost of land disposal of the wastes
- Cost in terms of human health and welfare
- Cost of filling available land disposal sites faster, thus requiring new sites

7.3 Elements of Effective Collection Programs

A successful collection program, must carefully select sources of used oil to collect, collection routes and locations, and collection equipment. The used oil must be of consistent quality and large enough quantity to justify a collection program. Industrial sources can be interviewed by trained laboratory personnel to determine the composition and consistency of their used oil. Collection routes and locations should be convenient to both the generator and transporter. Transporters should be equipped with pumping machinery, rubber hose, gauging sticks, fire extinguishers, and repair tools (1).

An important requirement for a successful collection program is public education. Used oil generators must be made aware that used oil is a hazardous waste, and that it can pose environmental problems if not managed properly. Teaching generators the fundamentals of waste segregation can

also greatly increase the collection program effectiveness. Proper segregation methods greatly reduce contamination by water, solvents and other wastes. This improves recyclability and reduces volume.

Effective publicity is an important element of a collection program. Posters, fliers, brochures, press releases, and public service spots on local television, radio, and newspapers can all publicize programs. Figures 7-1 and 7-2 show examples of collection program posters. Collection centers can be clearly identified by standardized logos. Handouts and brochures can publicize programs and highlight the importance of proper management. Clearly labeled containers remind generators to segregate and recycle used oil, as well as providing a place to store it.

Incentive programs can also aid of used oil collection programs. Whereas threats of legal penalties can foster negative feelings towards recycling, incentive programs promote positive feelings. Effective incentives dissuade generators from dumping used oil. Incentives can have monetary value such as prizes or discount coupons. They can also be promotional items such as funnels or used oil containers.

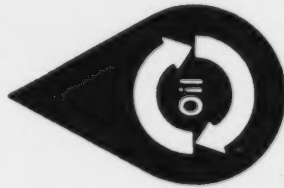
Training collection personnel help to make a program successful. Personnel screen used oil at the point of collection. A simple visual inspection can often reveal the presence of water, solvents, and solid contaminants. Personnel can also spot unusual colors. By screening used oil, unwanted contaminants can be minimized and used oil recyclability can be improved.

7.4 Current Status of Collection Programs in California

In 1985, 53.4 million gallons of used oil was collected in California. Table 7-1 shows sources from which used oil was collected for 1982 to 1985. It is projected that future volumes of collected and recycled used oil will decrease as the result of declining crude oil prices. The used oil industry is subject to state hazardous waste regulations. This places compliance costs on the industry. Many firms cannot afford insurance and capital costs required to update their equipment to comply with regulations (6). Registration of used oil companies dropped from 150 in 1985 to 115 in 1986. Due to increasing economic and regulatory restrictions, this trend is expected to continue. Only firms with solid economic backing, as well as equipment, expertise, and willingness to comply with environmental regulations, will survive. It is predicted that the future the used oil collection industry will be controlled by a small number of large companies.

USED MOTOR OIL COLLECTION CENTER SIGN

**USED MOTOR OIL
COLLECTION CENTER**



**Protect Our Environment
Conserve Our Resources
Recycle Used Motor Oil**

COLLECTION CENTER HANDOUT

**HELP CLEAN UP
YOUR
NEIGHBORHOOD!**

- Millions of gallons of oil are lost each year by motorists who change their own oil and dump the waste in sewers, on the ground, in trash cans, etc.
- Hundreds of collection stations across the nation have agreed to accept and recycle your used oil.
- If you're a do-it-yourselfer, take your used oil to these collection centers. You'll do your neighbors and your country a favor.



DISPOSE OF USED OIL PROPERLY!

Figure 7-1. Examples of collection program posters.



THE WORLD IS FULL OF TOXIC WASTE. YOUR HOME SHOULDN'T BE.

Many household products contain harmful chemicals. Often, these products are thrown in the garbage, buried in the yard or flushed down the drain. This may result in injury to people and animals or cause hazardous conditions in the sewer system.

NOW YOU CAN DISPOSE OF HOUSEHOLD TOXICS SAFELY!

The City of Sunnyvale has arranged for **FREE** disposal of your unwanted products. Bring these products to the recycling center on May 3.

PROTECT YOUR HEALTH AND ENVIRONMENT.

WHEN:

9 a.m. - 3 p.m.

Saturday, May 3, 1986

HOW:

Non-leaking disposable containers:

No more than 5 gallons of any type of material.

Questions: Call Public Safety during regular business hours 730-7160.

WHERE:

SUNNYVALE

RECYCLING CENTER

On the corner of Borregas -
one block north of Caribean



Figure 7-2. Example of collection day flier.

Table 7-1. Amount of used oil collected in California, 1982-1985

Used oil source	Amount collected (million gallons)			
	1982	1983	1984	1985
Collection Stations	29.2	22.1	30.1	30.7
Agricultural	1.4	0.3	0.5	0.9
Industrial	5.6	4.6	5.0	6.3
Governmental	1.3	1.3	3.3	1.1
Haulers	12.6	7.5	11.2	11.0
Sources Outside CA	3.7	1.3	1.8	1.6
Others	1.1	0.8	0.7	1.8
TOTAL	54.9	37.9	52.6	53.4

Source: Ref. (6).

7.5 References

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CHAPTER 8 REUSE AND REREFINING

8.1 Reuse of Used Oils

Nearly 52 million gallons of used oil were recycled in California in 1985 (1). This is about 40 percent of all used oil generated during that time. End uses of recycled used oil are shown in Table 8-1. These values are typical of those reported throughout the US. However, much of the used oil generated is not recycled. Large volumes reportedly (2) are managed illegally by pouring onto the ground, mixing with trash or garbage, and other unreported means. Discussions of the major reuse methods are given below.

8.1.1 Senate Bill 86 Standards

Senate Bill 86 (SB 86) became law in January 1987 and is now part of the Health and Safety Code. This bill, titled "Management of Used Oil," requires used oil to be handled, stored, and used in accordance with DHS laws and regulations. SB 86 defines used oil and recycled oil. It also requires that used oil be managed as a hazardous waste. Used oil that meets the criteria adopted pursuant to Section 25141 is not regulated by DHS. Any generator who claims that his used oil meets these standards must notify DHS of this claim and must comply with the testing and record keeping requirements of Section 25250.19. The burden is on generators and users to prove that the used oil meets standards.

Any virgin oil product or partially refined product that has not been previously used and has been contaminated with nonhazardous impurities is exempt from SB 86, according to Section 25250.3. Used oil must be managed as a hazardous waste in accordance with SB 86 until it has been recycled. Used oil that is not recycled must be disposed of or transported out of state as a hazardous waste.

SB 86 prohibits the following methods of disposal:

- Discharge to sewers, drainage systems, surface or groundwater, watercourses, or marine waters.
- Incineration or burning as fuel, unless authorized by other provisions of law.
- Deposit on land.
- Use as dust suppressant or weed control agent.

Any person who handles used oil shall not intentionally contaminate it. He shall not knowingly accept used oil that has been contaminated with other hazardous wastes, other than minor amounts of vehicle fuel. SB 86 also provides for a modified manifesting system.

Table 8-1. End uses of recycled used oils in California (1985)

End use	Volumes of used oil	
	Millions of G/Y	Percent of total
Motor Oil	0.7	1.4
Industrial Oil	2.0	4.0
Fuel Oil	41.7	80.0
Asphalt	4.8	9.3
Road Oil	0.6	1.2
Other Recycled	2.1	4.1
TOTAL	51.9	100.0

8.1.2 Used Oil to Fuels

The most economically attractive way to manage used oil is to burn it as fuel. Of the total used oils reprocessed in California, about 80 percent, or nearly 42 million gallons per year, are utilized as fuel. Based on extensive discussions with California used oil recyclers, most is blended into bunker fuel oil for ships. California regulations prohibit blending used oils with virgin fuels. However, used oils can be blended with other used oils authorized facilities to meet existing fuel oil regulations. Any facility capable of burning bunker, #6, #5, and #4 fuel oils can handle recycled oils. The reason for this is that these oils contain residual petroleum oils which already include a certain amount of water and solids. Most used oils require treatment prior to blending into the above fuel oils. This treatment generally consists of settling, often with assistance of heat, filtration, and removal of volatile materials. These processes are unable to remove metals. Processing of used oils can be done at authorized facilities by knowledgeable personnel.

The environmental impacts of burning used oil depend upon (3):

- Concentration of hazardous contaminants in the oil
- Burner design
- Emissions control equipment
- Stack height
- Meteorological conditions
- Number of emitting sources within an area

Reference (3) provides details on contaminant concentrations. A recent EPA report (4) examines the other factors regarding the risks associated with burning used oils.

For the generator who wants to burn used oils onsite, the major concerns are meeting required fuel oil specification for which his boiler and burner are designed, and the DHS recycled oil standards. Recycled oils used for fuels should not contain materials with a flash point below 100 °F or halogenated materials. Guidance on segregation of oils is discussed in Section 6.3.

8.1.3 Recycling

As indicated in Table 8-1, the major option for used oils other than fuel use is recycling to produce lube or industrial oils. This recycled product generally meets original product standards. In many industrial operations, oils may be used to flush, clean or test equipment and thus become only slightly contaminated and are easy to recycle. In other operations, oils become contaminated with easily removed substances. These used oils may only require simple treatment to restore the product to its original quality.

Contaminants are removed to restore the oil to a quality which makes it suitable for reuse, and make it nonhazardous. A description of equipment and facilities is given below, followed by specific comments on recycling.

Recycling includes physical processes such as centrifugation, coalescence, distillation-evaporation and gravity settling. A complete system may contain one or all of the operations described below:

Centrifugal Separators - Separate solids from used oils when settling rates need to be enhanced and gravity separators require too long a residence time. They are also used when space limitations require small volume equipment. Centrifugal separators have large power requirements. They are not effective when solids are trapped in emulsions.

Coalescers - Provide large surface area media that attract the water phase of an emulsion and repel the oil phase. For water removal, an emulsion of used oil is pumped through the media. Water droplets attached to the surface coalesce, are separated, and are removed. Often, filtration and coalescence are accomplished together in a combined filter-coalescer. Such units are commonly used to remove solids and water from jet fuel and other distillate fuels. Coalescers can remove water from oil down to levels of 5-10 ppm oil.

Distillation Columns - Evaporators - Improve the quality of used oils based on differences in volatility of impurities and the material to be purified. These units can remove water and highly volatile, low flash point, fuels and solvents from high flash point fuels and lubricants.

Filters - Separate solids from used oil streams. The nature of the filter media and design of the unit depends on the particle size and concentration of the solids to be removed. Typical media include sand, clays and fibrous media. Filters can also be selected to coalesce and remove water.

Gravity Separators - Tanks of various designs that separate oil, water and solids by providing sufficient residence time. Separation occurs by gravity and buoyant force. Many gravity separators are equipped with skimmers and pumps for water and solids removal. Heaters can be incorporated to enhance separation rates. Gravity separators are effective for oil and solids removal when the used oils are free of emulsions and when sufficient time is provided for settling. Effluent water streams from gravity separators may contain up to 200 ppm oil. High oil levels usually require further secondary treatment to reduce oil levels to regulatory limits.

Used Lube Oils

Recycling used oils to provide lube oil base stocks will be discussed in Section 8.2. This section only deals with lube oils recycled for other purposes.

Lube oils are often used for flushing out engines or for brief engine testing after repair. In such applications, the oil may become only slightly contaminated with metal parts, water, solvents or other materials. These oils do not experience severe service. They can often be recycled

easily. Methods and equipment are listed below that can restore oils to required quality.

- Treatment to Remove Water and Solids - Done by processes and equipment that strip off volatile water and separate out solids. Equipment includes heat, vacuum units, centrifuges, and filters. Equipment examples are listed in Table 8-2. A generator wishing to try such equipment should send a used oil sample to the equipment supplier. The supplier will test the suitability of their unit to produce oil of the desired quality.
- Removal of Solvents - Some industries need to flush out equipment containing oils or other fluids with chlorinated or freon solvents. Consequently, wastes are produced containing 5 to 40 percent solvent in oil. The resulting mixture generally must be managed as a hazardous waste. Steam-stripping can remove the volatile solvent from the oil. The solvent can be reused and the oil used for fuel or other purpose. This avoids disposal. Steam-stripping is required rather than a simple, conventional solvent distillation unit. The latter "pot stills" are excellent for solvent recycling. However, they cannot completely strip the solvent from oil. Suppliers of equipment are noted in Table 8-2. These units can be obtained in various sizes. They cost about \$25,000 for a 10 gallon per day unit. Larger units are also available. Experience has shown such equipment and procedures for stripping solvents from oil can readily meet economic and environmental requirements.

Hydraulic Fluids

The two major types of hydraulic fluids are conventional and fire-resistant materials. Conventional hydraulic fluids are Table 8-2 high-boiling hydrocarbon oils derived from petroleum. These are similar to lubricating oils, but generally contain less and different additives.

Fire-resistant hydraulic fluids may contain phosphate esters, polyglycols, polyolefins, silicones, silicate esters, chlorofluorocarbon polymers, fluoroesters and blends of these compounds. Water-based systems containing these materials are also available.

Recycling of non-water-based hydraulic fluids can be accomplished by:

- Removal of Water and Solids - The same type of equipment and procedures described for lube oils in the previous section.
- Removal of Solvents - Hydraulic fluids are often contaminated with chlorinated or freon solvents. These can be removed, as discussed above for lube oils.

The above means are not suitable for all applications. Generally, for critical uses such as in aircrafts and ships, virgin hydraulic fluids are mandated. Use of recycled hydraulic fluids must be determined for each application. The recycled fluid must be tested to assure compliance with the required specifications.

Table 8-2. List of equipment suppliers for reclaiming oils*

Supplier	Throughput G/hr	Costs \$K	Comments
Allen Filters Inc. P.O. Box 747 Springfield, MO 65801 417-865-2844	N/A **	N/A	Patented trays provide thin-film evaporation. No coalescer needed. Low maintenance.
Baran & Associates Inc. P.O. Box 2997 Cookeville, TN 38502 615-528-8476	75-1200	N/A	Use vacuum and heat to flash off volatiles. Plus filters for solids.
Gulfgate Eng. Inc. P.O. Box 262524 Houston, TX 77207 713-644-5558	30-3000	5-20	Offer low and high vacuum systems plus filter/separator.
Pall Corp. East Hills, NY 516-484-5400	N/A	N/A	
Petrotech Division of Aquanetics Inc. P.O. Box 745 Hacketstown, NJ 07840 201-850-3970	180 & up	13 & up	Vacuum distillation and filtration equipment.

* This list is provided for illustrative purposes only and does not give all suppliers of such equipment. No endorsement or recommendation of this equipment or suppliers is to be implied.

** N/A = Information not available

Recycle of water-based hydraulic fluids is similar to recycle of emulsified oils. Emulsion breaking is required to separate out water and recover the oil. The water and separated oil are then managed as required.

Certain fire-resistant turbine fluids, especially organic phosphates and polyglycols, can be recycled by returning them to the supplier or to companies who sell them as plasticizers. The recycler may pay up to \$0.25-\$1.00/gallon for used hydraulic fluid if there is less than 2-5 percent oil contamination. One firm which accepts used hydraulic fluid is:

Hydrocarbon Recycling
5354 W. 46th Street
Tulsa, OK 74157
918-446-7434

Hydraulic fluids can also be recycled as fuels by blending other oils, such as lubes.

Turbine Oils

Both petroleum-based and synthetic oils are used as turbine oils. The synthetic oil basestocks consist of di, tri and polyesters of organic acids. The latter are very stable, with minimal oxidation degradation. Generally, all aircraft turbine engine oils are synthetic.

Recycling of turbine oils is extensive in industry. However, no reclamation process has proven acceptable for aircraft standards in the US. However, it is done in European and other countries. The major reclamation options for aircraft turbine fluids are:

- Use as a plasticizer
- Blending with oils for burning as fuel

Other turbine oil users commonly reclaim their oils. The equipment noted in Table 8-2 is used for turbine as well as hydraulic oils. The heart of this equipment is a 150 °F vacuum still. The still flashes off volatile contaminants such as fuel and water. Turbine oils can also be blended with other oils for fuel.

8.1.4 Use as Asphalt

Asphalt compositions vary considerably because they are used for many applications. The major uses for asphalt are road paving, waterproofing, tile cements, linoleum backing, caulking compounds, and adhesives. Products include coal briquettes, paints, expansion joint fillers, industrial floorings, wire coatings, sound-deadening cements, linings for reservoirs and irrigation ditches, and revetment coverings on beaches.

Due to varied requirements, asphalts differ in properties and composition. Most asphalt applications undergo slow oxidation of components which tend to polymerize and harden with time.

High flash point bottoms from reprocessing operations are commonly added to asphalts as plasticizers and extenders. It has been found that high flash bottoms actually contribute other beneficial properties to asphalts. For example, used lube oils contain polymers to improve viscosity index, solids and other materials which improve asphalt. However, blending of high flash bottoms with asphalts requires knowledge of the composition of the oils and their impact on the final product.

8.2 Rerefining Description

8.2.1 Use of Simple, Partial Rerefining Procedures

In-house recycling methods can include:

- Testing of used oils to see if they can be reused.
- Static separation of known contaminants, which is only useful for some used oils. This normally does not rid oil of contaminants. however, it may extend useful life of lubricating oil.
- If tests show that used oils meet the standards of purity of Article 13 HSC, then they can be recycled as fuel.

8.2.2 Rerefining Economics

The economics of rerefining are dependent on waste oil cost, capital cost, working capital required, manufacturing costs, and revenues from the rerefined products. Economics are based on competition. Rerefiners compete for used oil feedstock with other transporters and reprocessors. Since reprocessors' operating costs are lower, they can often charge less for collection. However, their final product is usually burned, while rerefined products are reused. Rerefiners also compete with virgin lube oil marketers when selling the rerefined lube products.

A large portion of a rerefiner's expense is the cost of the used oil. Used oil is the raw material for the rerefinery. Rerefiners with their own collection fleets have to consider the economics of collection as well. The quality of the used oil must be checked to insure its value as a feedstock. Contaminants can adversely affect product yields and profitability. Used oil cost varies with the quantity, quality, location and transportation cost, and the price of new oil.

Capital costs account for land and its preparation, equipment and its erection, buildings, offices, laboratories, transportation equipment, and working capital. Working capital is required for used oil inventories, supplies, rerefined oil inventories, extended credit and sufficient cash to meet all the bills for at least one month.

Various cost estimates are combined to determine the manufacturing cost per day or per gallon of product. Manufacturing costs include supplies, materials, labor, insurance, taxes, fees, administrative and sales expenses, shipping, laboratory, overhead, and utilities.

Profitability and payout time depend on annual costs and revenues. The revenues include by-product sales.

8.2.3 Uses of Rerefining Product Streams

Light Ends/Light Fuel Overhead Streams

Liquid fuels are recovered in the dehydration stage and in the finishing or vacuum distillation step. These streams are most commonly used for plant combustion fuel. Alternatively, gasoline and diesel boiling range fractions could be used as internal combustion fuels. If these streams can meet the required specifications, they can be marketed and sold as recycled fuel oil. Chloride content may restrict use as an internal combustion fuel. Without removal of chloride contaminants, the gasoline fraction would be unusable as a gasoline component. Due to the cost of chloride removal and the small quantities of gasoline normally found in used oil, use as a boiler fuel is probably the best option economically.

The diesel fraction may contain high chloride and sulfur content. Hydrotreatment of this fraction can produce high quality diesel fuel. Alternately, this fraction could be sold as a fuel blending stock.

The gas oil fraction presumably represents a loss from the lube stock. If distillation is available to recover lower fractions, this fraction can be recovered as well. It can then be returned to the lube pool or used as an asphalt flux.

Distillation Bottoms

Residual streams from distillation can be classified as either low boiling lubricants or asphalt bottoms. Rerefiners trying to maximize the production of lubricants can distill as much of this boiling range material as possible. The residue is similar in boiling range to normal vacuum residuals. The second product purposely has a certain amount of lube stock in the bottoms stream. This produces a valuable asphalt flux.

Rerefiner bottoms streams cover the same boiling range as normal vacuum residuals. However, they are distinguished by high concentrations of metals, ash, viscosity improver polymers, and oxygenated compounds. The bottoms stream is used by asphalt industry as an asphalt flux. The asphalt industry can use this component in production of roofing asphalt, paving asphalt, sound deadening materials, insulating materials, and other asphalt based products.

8.3 Rerefining and reclaiming processes

The options available to generators of used lubricating and hydraulic oil include reclamation, reprocessing and rerefining. Reclamation removes water and solids from the used oil. Reclamation uses heat, gravity settling, and either screening, centrifugation, or filtration. Reclamation is the same as discussed earlier for oily wastes except that wastes being processed contain much less water. The products are usually fuels, fuel supplements, and concrete form oil. However, in cases where hydraulic oil is well segregated from contaminants, it may be recycled for its original use.

Reprocessing removes water, solids, and some oil-soluble impurities. It uses heat, surfactants, chemicals, clay treatment, filtration, and centrifugation. The products are clean fuels, metalworking base stocks, noncritical lubricants, and concrete form oils. Some oils can be processed to original quality for reuse as lubricating oil, especially in noncritical service.

Rerefining is just what its name says, the complete rerefining of the waste oil. The product is essentially indistinguishable from the virgin crude oil product. To get this product quality, it is necessary to remove water and solids, distill off light ends at atmospheric or slightly reduced pressure, and take the lube fraction overhead under high vacuum. Further purification is achieved by either propane deasphalting or solvent treating before the lube distillation, or by hydrotreating or clay treating after the distillation. These processes will be discussed in more detail below.

8.3.1 Quality and Quantity of Waste Oil

Optimum waste oil management depends on the quality and quantity generated at a given site. It is desirable to do some treating as near the source as possible. However, with small operations, economics are favorable only for the simplest treating techniques. It is recommended that small companies with similar oil types form a cooperative to build a treatment facility and share in the economies of a larger size plant. Furthermore, it is tempting to pour all the waste into a common container and thus further complicate recovery. Careful segregation of oil from solvents and oily water can make it much easier to manage these wastes.

8.3.2 Onsite Options

The main economic driving forces for onsite treatment are:

- Hauling cost of approximately 25 cents per gallon.
- Value of reclaimed oil of 50 to 80 cents per gallon to the generator by replacing purchase of new oil.

These numbers change with time and with geography. Not long ago the generators were paid for used oil by transporters. Now they are usually charged to have the oil transported. In areas where used oil is in demand for ships bunker fuel, this competition affects the price structure for collection and removal. Each generator must evaluate the options locally available.

Onsite treatment requires space for equipment, capital investment in the equipment, and personnel to operate the equipment. This means that there is an economic balance between the size of the generator and the complexity of treatment. Small automotive shops vary in monthly oil generation from 100 to 2500 gallons, averaging 500 (5). Most of these shops have their oil hauled at prices varying from a charge paid of 25 cents per gallon to a payment received of 15-20 cents per gallon. Good onsite segregation from solvents and water, including rain, must be done to minimize cost.

As the volume of the waste oil generated increases, more complex treating plants become economical. It has been estimated (6) that at 200 gallons per day it becomes attractive for machine shops to process oily wastewater onsite for volume reduction instead of having it hauled away. Such an operation cannot be justified by the value of the oil. It is justified by the reduction in hauling cost. However, where there is relatively little water and solvent contamination, the recovered product can have fuel value and possibly even new product value. Each application must be evaluated on its own merits.

In the past, onsite uses (7) for recovered oil included:

- Fuel for waste oil space heaters.
- Burning as a diesel fuel-used oil mixture in vehicle engines.
- Mixing with fuel oil for burning in onsite boilers.

However, each of these options has been shown to cause environmental problems. They are now illegal in California.

8.3.3 Offsite Options

In contrast to the limited onsite options available to the small generator, there are many offsite options. Offsite management services process waste from many generators. This gives the economic benefits of scale, even though transportation is required. Much more complex treating procedures can then be used.

The reasons for choosing offsite instead of onsite waste management fall into a few basic categories (8):

- Lack of technical and physical resources.
- Onsite management not part of firm's mission.
- Established company practices.

For the small generator, the first reason is most compelling. The offsite options are the same as those that can be used onsite for very large generators. That is, reclaiming, reprocessing, and rerefining are all viable. The recovered oil can sometimes be burned as fuel or returned to the original use. Oils which cannot be successfully reprocessed can be burned in permitted cement kilns.

The unit operations that combine into a treatment facility vary from one recycler to another. Each is some combination of the unit operations given in Section 4.3.

During the 1970s there was great fear that the supply of petroleum was quickly vanishing and that prices would become unprecedentedly high. Extensive research was done during this period on recycling used petroleum products. This led to a multitude new ways to rerefine waste oil streams. The time honored system of treating with sulfuric acid and clay was no

longer acceptable due to growing environmental concerns. New process innovations assumed a feed stock for which solids and bulk water had already been removed. The processes were based on research in Europe, the United States, and Japan. Those that reached the development or commercial stage include:

- Recyclon Process (Switzerland-West Germany)
Developed by collaboration of Leybold-Heraus, Adolf Smids Erben, Inc. (ASEOL), and Degussa, (10).
- Krupp Process (West Germany)
Developed by Fried. Krupp. (15).
- KTI Process (Netherlands, California)
Developed by Kinetics Technology International (KTI) in collaboration with Gulf Science and Technology Co. (9,10,12).
- IFP Process (France)
Developed by the Institut Francais du Petrole (IFP) (9,12).
- Matthys Process (France)
Developed by Pierre Matthys (17).
- Snamprogetti Process (Italy)
Developed by Snamprogetti S.P.A. (9,13).
- Dieselclene Process (United Kingdom)
Developed by British Railways (16).
- PROP Process (U.S.A.)
Developed by Phillips Petroleum Co. (10).
- BERC Process (U.S.A.)
Developed by Bartlesville Energy Research Center (12,13).
- RTI Process (U.S.A.)
Developed by Resource Technology Incorporated, Kansas City.

These processes all have distinguishing features. Each process is part of a general approach to rerefining used motor oils. This general approach is as follows, but not always in the order presented:

1. Remove water.
2. Remove additives and sludge.
3. Remove dissolved low boiling hydrocarbons (fuels) and solvents.
4. Remove impurities (metals, chlorides, etc.).
5. Fractionation.
6. Perform final finishing.

In general, water and dissolved low boiling point organics are removed by atmospheric or moderate vacuum distillation. Lube oil is recovered and fractionated by distillation at absolute pressures of 1 to 50 mm Hg. The major differences are in how additives, impurities, and sludge are removed, and in the final finishing step. The techniques for removing additives, impurities, and sludge fall into the following categories:

Chemical Treatment

- PROP Process uses precipitation with aqueous ammonium sulfate or bisulfate at elevated temperature and pressure. This is followed by separation of the solid reaction products from the oil.
- Recyclon Process uses sodium treatment followed by distillation overhead of the low boiling reaction products.
- IFP Process uses reduced amount of sulfuric acid treatment.
- Matthys Process uses reduced amount of sulfuric acid treatment.
- Dieselclene coagulates contaminants and removes them as insoluble matter, leaving unused portions of the additives.

Clay Treatment

- PROP Process uses clay treatment to remove metallic components.

Extraction Techniques

- IFP Process uses subcritical propane precipitation.
- BERC Process uses a mixture of oxygenated solvents to reduce coking and fouling precursors.
- Krupp Process uses supercritical extraction with propane or other light gases for fractionation and sludge precipitation.
- Snamprogetti Process uses paraffin extraction to eliminate metals, sludge, and additives.

Vacuum Distillation

- Recyclon Process uses short path vacuum distillation to recover oil and reject residue.
- KTI Process uses wiped surface vacuum stills for recovery of lube fraction and rejection of residue.
- BERC Process uses vacuum distillation for recovery of the lube fraction.
- Snamprogetti Process uses vacuum distillation for viscosity grade separation.

- RTI Process uses cyclonic vacuum distillation for recovery of lube fraction.

Membrane Processes

- IFP Process uses a pretreatment modification which dilutes oil with three volumes of light naphtha and uses ultrafiltration to remove sludge and additives.

The final finishing step is usually either hydrogenation, clay treatment, or distillation:

Hydrogenation

- PROP Process.
- KTI Process.
- IFP Process.
- BERC Process.
- Snamprogetti Process.

Clay Treating

- Matthys Process.
- Krupp Process.
- RTI Process.

Distillation

- Recyclon Process.
- KTI Process for base stock fractionation (optional).
- RTI Process.

All of the above rerefining processes are technically feasible. The tests of time, commercial economics, and ease of operation have narrowed the choices for new plants in the U.S. and California down to one of four types:

- 1) solvent treatment/distillation/hydrotreating,
- 2) vacuum distillation/clay polishing.
- 3) chemical treatment/demetallization/clay polishing.
- 4) vacuum distillation/hydrotreating

Each is distinct because of waste materials generated, by-product and product marketability, and the applicability of environmental regulations and control options (18). Some rerefiners are also involved in used oil reprocessing, either on a regular basis or according to product demand and feedstock quality. Therefore, the equipment needed to reprocess used oil is

already available. Reprocessing merely bypasses some rerefining process steps.

Due to the economies of scale, rerefiners tend to be larger than used oil processors. Rerefineries range in size from 10 to 20 million gallons per year. Furthermore, modern rerefiners use primarily vacuum distillation technologies. There is growing reliance on wiped surface stills. One of the two major rerefiners in California, Evergreen Oil Inc. uses the KTI Process. The other, DeMenno/Kerdoon, use its own vacuum distillation process. It is believed that any new plants will be based on vacuum distillation and hydrofinishing. This will eliminate disposal problems due to chemicals and clay used in the treating process.

8.3.4 Environmental Impacts

Technological and management trends of the used oil recycling industry are heavily influenced by the processing by-products. For example, acid treatment generates an acid sludge. This sludge must be disposed of as a hazardous waste at a permitted landfill at considerable expense. Disposal of clay from clay treatment is also getting prohibitively expensive. This means that the processes which do not generate hazardous wastes that are difficult to manage will be preferred in the future. This is one of the major reasons behind the trend toward vacuum distillation and hydrogenation finishing.

8.3.5 Conclusions and Recommendations

Increasing environmental constraints on waste oil management is increasing the cost of recycling oil. This will tend to drive the small recycler out of business and favor the large operator who can spread costs for permitting and analytical work over a much larger base. Furthermore, the increasing expense of managing process by-products such as sludge, spent clay, and acid, will favor processes that generate no by-products. Higher investment processes benefit from large scale. This should help stabilize costs for the small generator who has his waste treated offsite. However, it will make only the simplest treatments economical onsite.

8.4 Rerefining Case Study: The KTI Process

8.4.1 Process Description

The KTI Process consists of several steps. Each step serves as a "sieve," separating a specific group of contaminants. Contaminants are classified by their physical and chemical properties and concentration. Figure 8-1 is a flow diagram of the KTI Process.

The process steps used to recover or rerefine the lube oil are:

- A. Separation of the lube oil components from used oil by physical processes such as vaporization, distillation, and stripping.
- B. Finishing of the separated lube oil by hydrotreating.

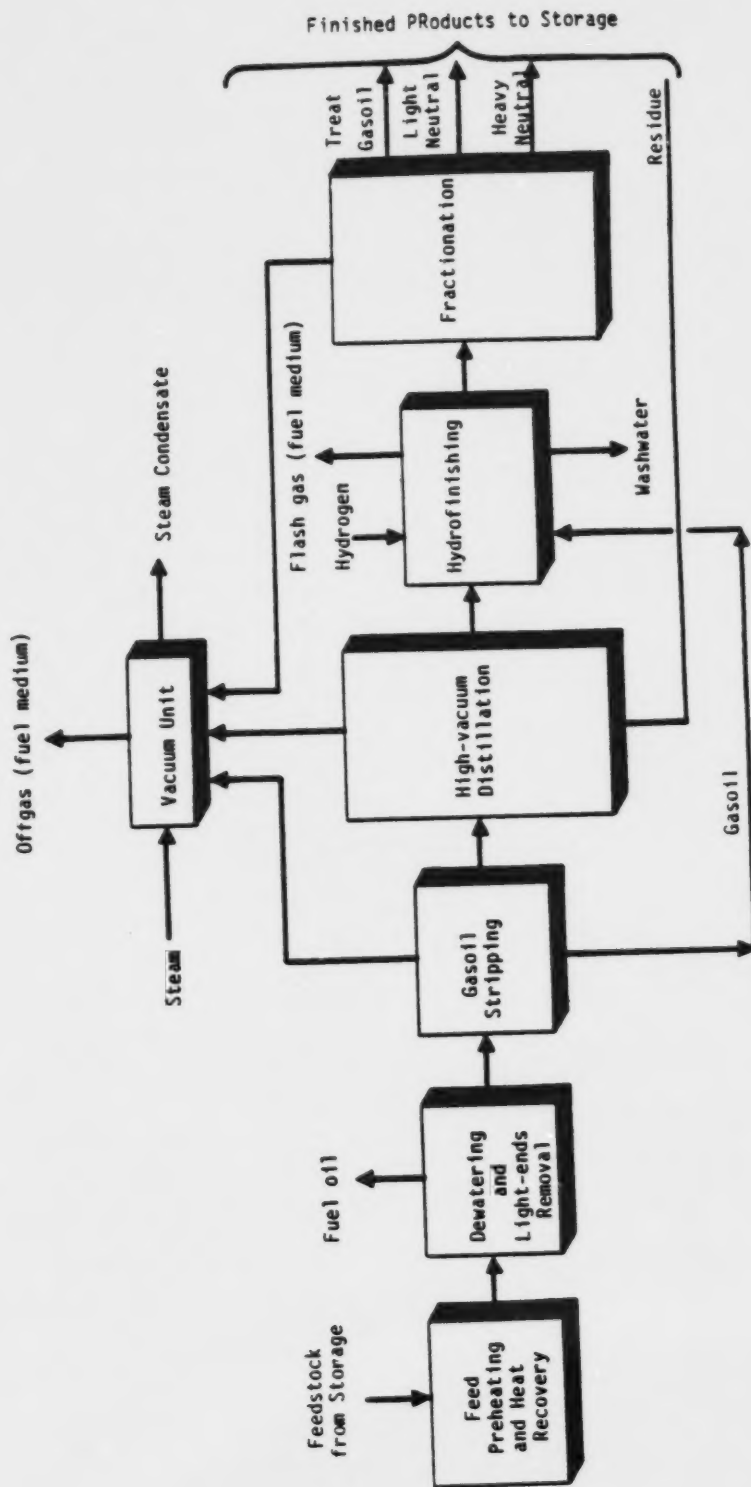


Figure 8-1. Flow diagram of KTI Process (9).

Most non-lube oil components have different boiling ranges than lube oil. Only fatty acids, esters, some chlorinated compounds, and some additives have similar boiling ranges. These compounds remain mixed with lube oil after distillation. They are removed in the finishing step.

8.4.2 Separation of Light Components

Light components are separated by vaporization and stripping. In the first step, water, gasoline, and light boiling components such as trichloroethylene are removed. This is done by atmospheric flash evaporation at approximately 150 °C. Light boiling components include gasoline, solvents, and glycol. In the second step, dewatered spent oil is further distilled to strip off gasoil (diesel fuel). Fractionation is used to separate gasoil from lube oil. This minimizes lube oil loss. Distillation is performed under vacuum at about 270 °C.

8.4.3 Separation of Heavy Components

Lube oil components and co-boilers are separated by flash distillation. In the third process step, heavy components are concentrated in a residue stream. Due to fairly high solids content and high hydrocarbon molecular weight, vacuum distillation is carried out in a special wiped film evaporator. Temperatures above 340 °C crack lube oil components. This avoids fouling of heat transfer surfaces. The heavy components consist of additives, metals, and degradation products. They are concentrated in asphalt flux, which is used as roofing material.

8.4.4 Hydrofinishing/Fractionation

In the fourth step, contaminants which boil in the same range as lube oil are removed by catalytic hydrogenation. The lube oil distillate is purified by treating with hydrogen. This treatment removes the co-boiling impurities that distill over with the lube oil fractions. These impurities are primarily chlorine, oxygen, and nitrogen containing organic compounds. Upon hydrogenation, they form gasoil, ammonium chloride, and water. A part of the organic sulfur is also removed and forms hydrogen sulfide. Light gaseous paraffins are formed. The hydrofinished lube oil is separated from the gaseous products by flashing at low pressure. It is then fractionated into a gasoil fraction and a lube oil fraction. The lube oil fraction is further split into heavy and light products.

8.4.5 Characteristics of the KTI Process

Feedstock Flexibility

To be successful, a rerefining process must have great flexibility in dealing with contaminants. The KTI Process features high selectivity for separating hydrocarbons from non-hydrocarbons.

High Product Yield

Increasingly complex lube oil additives have made conventional used oil reprocessing techniques, such as the acid/clay process, more difficult to operate. This has reduced lube oil yield. Reduced yield is one reason for

the recent decline in rerefining. The KTI Process recovers over 95 percent of lube oil components. This makes the KTI Process significantly more economical than conventional processes.

Product Quality

Years of operational experience have shown that the KTI Process produces a product equivalent to virgin lube oil. Product quality is very important for marketability and consequently for the success of a rerefinery. Table 8-3 shows typical characteristics of rerefined and virgin lube oils. Of most importance is that rerefined lube oils retain their original viscosity and viscosity index properties. Rerefined lube oils also show excellent oxidation stability and good response to oxidation inhibitors.

Destruction of PCBs, PCDDs, and Furans

Operating experience and laboratory tests have shown that PCBs, PCDDs, and furans present in the rerefining distillates react in the hydrofinishing section. They form non-polluting hydrocarbons and HCl.

No Hazardous By-products

By removing hazardous and bulky by-products, handling and disposal costs are minimized and product loss is avoided. Streams generated during the process include:

Light Boiling Hydrocarbons: While chlorine content in the light boiling fraction is great concern to many rerefiners, the KTI Process uses light boiling hydrocarbons as process fuel. Light hydrocarbons are burned in a special incinerator.

Distillation Residue: Additives, ash components, and sludge containing metals and other inorganic contaminants are concentrated in a highly viscous, bituminous product. Tests have shown that no metals leaching occurs. This product is suited for use as an asphalt extender.

Wastes: No solid by-products other than spent catalysts are generated.

Effluents: Waste water is produced by the vacuum system as drive stream condensate, by the fractionation section as stripping steam condensate, and by the hydrofinishing section as wash water. This waste water is subject to local regulations. It is treated to standards which are accepted by the municipal waste water system.

8.4.6 Commercial Status

KTI has significant experience in the reprocessing and rerefining of used lubricating and industrial oil. Rerefining plants utilizing the proprietary KTI Process commercially operate in Aspropyrgos, Greece; Bizerte, Tunisia; Newark, California; and at the largest rerefiner in the world, Dr. Anton Maier AG, Germany.

In 1982 the first rerefining plant to utilize the KTI Process was completed. This 20,000 metric ton per year rerefinery has produced premium grade

lubricating oils since that time. It was designed and constructed on behalf of VAROIL S.A. and is located in Aspropyrgos, Greece. The most recent KTI rerefinery was built in Newark, California.

Table 8-3. Product Quality Data for Virgin and Rerefined Oils

	KTI Rerefined Oil		Virgin Base Oil 150 Neutral
	Light Neutral	Heavy Neutral	
Elements:			
- Sulfur, mass %	0.3	0.4	0.32
- Chlorine, mg/kg	10	10	-
- Other metals, mg/kg	1	1	4
Color (ASTM) ₂	L 1.5	L 1.5	L1.5
Viscosity, cm ² /s (40 °F)	13.05	95.28	30.08
Viscosity Index	98	99	107
Conradson Carbon mass %	0.01	0.02	0.07
Total acid no. mg OH/g	0.01	0.03	0.05
Unsulphonated res. vol. %	96	98	94
Oxid. Stability IP40			
Ratio kin. viscosity at 40 °C	1.12	1.20	1.36
RCR increase, mass %	0.42	0.68	1.00

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CHAPTER 9 COMBUSTION

9.1 Description and Goals

Thermal options destroy used oils by altering their chemical structure to form less hazardous products. These options ensure that the generator's liability ends with disposal. Thermal process emissions may occasionally be harmful due to improper design or operation. Careful operation can ensure harmful constituents in the effluent are minimized.

Thermal options can be classified into two basic categories:

- Destruction
- Energy Utilization

The primary focus of the first category is destruction of the waste. The heating value of the oil is not used, except for combustion stability purposes. The second category utilizes the oil's heating value for some useful purpose.

State and federal regulations limit the types of devices that can be used for destruction. On-spec oils can be burned as fuel in any appropriate device. Used oils not meeting these specifications can only be burned in properly permitted incinerators. Operating permits must be obtained from the EPA, DHS, the local air quality control district, and other local governmental agencies. The permits are issued only when the unit has demonstrated that it will not release harmful amounts of any dangerous materials into the environment.

9.2 Incineration for Destruction

Devices used for destruction are designed to handle virtually all used oils. No effort is made to obtain recycled products or energy. This makes these processes useful only when recycling is not practicable.

The two classes of destruction are uncontrolled incineration, or flaring, and controlled incineration. Uncontrolled incineration atmospherically burns used oil in an open flare. Little effort is made to control the combustion or the exhaust gases. In controlled incineration the combustion is strictly monitored and controlled. This insures nearly complete conversion of organics to carbon dioxide and water. Composition of the exhaust gases is monitored and undesirable products are removed.

9.2.1 Uncontrolled Incineration

Regulatory Considerations

Only oils which meet the specifications can be burned in a flare. The flare must also satisfy local and federal air pollution control regulations. These regulations limit emissions of carbon monoxide, nitrogen oxides, ozone, soot, and other harmful materials. Local requirements depend on the regional air quality and the prevailing public attitude. In some areas,

such as the South Coast Air Quality Management District (the Los Angeles area), regulations are so strict that they essentially preclude these devices.

Technical Considerations

When organics are exposed to oxygen at high temperatures they react to form carbon dioxide, water, and other oxidized compounds. These reactions are fast but not instantaneous. Three key factors are temperature, oxygen concentration, and residence time. Effective incineration methods maintain used oils at high temperatures with enough oxygen for sufficient times to oxidize organic material into vapor and gas. Because of practical limitations, this conversion is not 100 percent.

Flaring is the least effective and simplest incineration technique. Oil is injected into the atmosphere in a fine spray. The spray ignites and forms a flame. The heat is supplied by the burning oil or by an auxiliary fuel. Oxygen comes from the surrounding air. The time that materials spend at incineration temperatures is controlled by the injection rate. Lack of tight controls over conditions often results in unburned materials leaving the flame. It is possible for trace amounts of toxic materials such as dioxins, furans and PCBs to form in the flame. Flares also can generate common air pollutants such as carbon monoxide, nitrogen oxides, and solid particles. Flares can only be used to burn relatively clean fuels with high heat content. Poorly performing flares and other incinerators of oil waste may generate oily black smoke. Therefore flares should be only for emergency flaring of oil which would otherwise be released uncontrollably into the environment. Better alternatives may also be available for that purpose.

Economic Considerations

Flares can be constructed quickly and inexpensively compared to incinerators. However, oils suitable for flares can also be processed to produce a useful product or can be sold as fuels. Thus flares are rarely used. Flaring is economical only when transportation costs preclude alternatives.

Current Practice

Current reports indicate that no oil is flared in California (1). This may be due to flared oils not being reported. However, because of economical alternatives, it is likely that no oil is flared in California.

9.2.2 Controlled Incineration

Regulatory Considerations

Federal, state and local laws regulate the controlled incineration of used oils. Incineration units must obtain permits from EPA, state, and local agencies. The regulations which apply depend on the composition of the oil to be burned.

Technical Considerations

Nearly any oil can be incinerated. Oils with high heat content are easier and less expensive to incinerate. Thus, wastes with high solids or water content are less suitable for thermal destruction than relatively pure used oils.

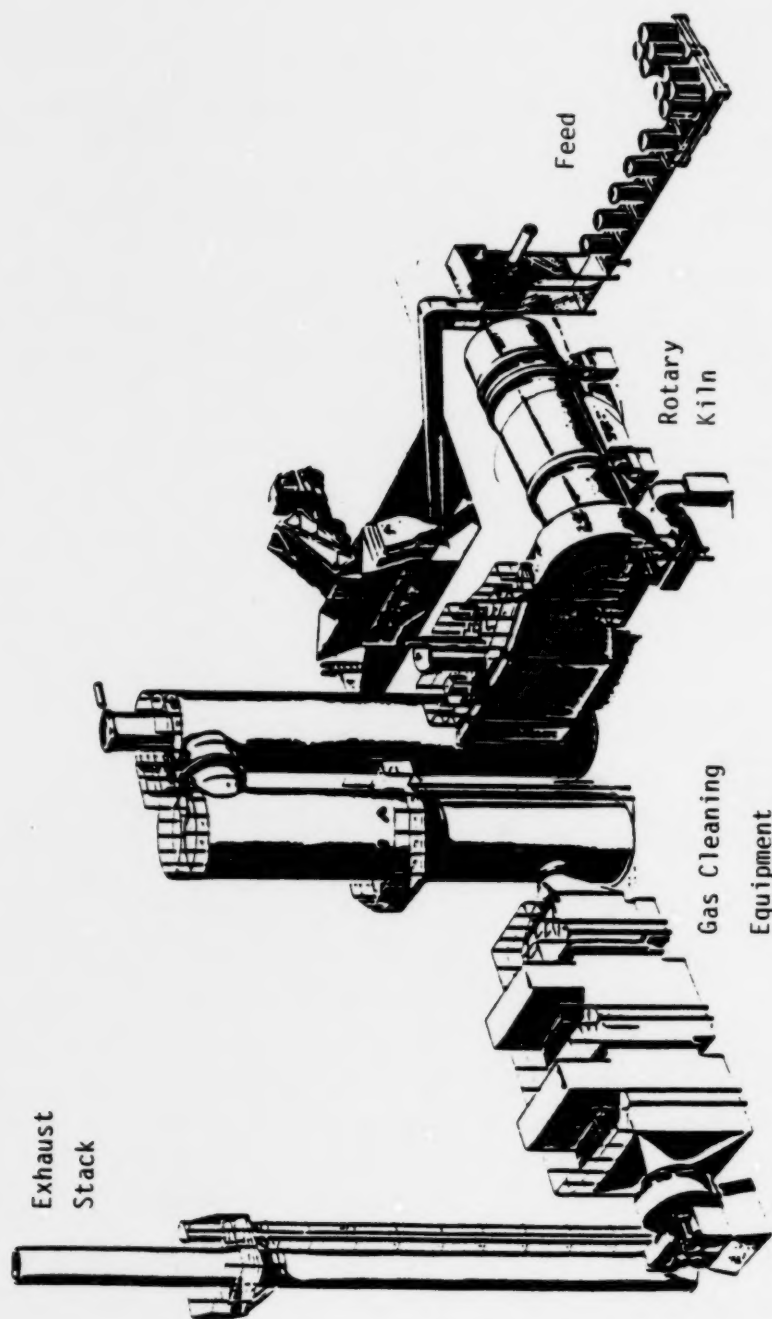
Controlled incineration is designed to approach complete combustion of organic material into oxidized gas and vapor. This is accomplished by maintaining the material at high temperature for sufficient residence time. The combustion gases are agitated to insure that oxygen is mixed throughout the incineration reaction. Harmful gases are removed from the exhaust before it enters the atmosphere.

Two types of incinerators are commonly used. These are the liquid injection incinerator and the rotary kiln. In a liquid injection incinerator the oil is injected into a tubular chamber where it is ignited and burned. This device is used for oils containing small amounts of solid materials. A typical rotary kiln is shown in Figure 9-1. This type of device can make use of an auxiliary fuel and can burn any type of used oil. Often both rotary kiln and liquid injection incinerators consist of two chambers. The gases from the first chamber are forced through the second chamber (the afterburner) where auxiliary fuel is used to maintain high temperature. The afterburner insures that any material escaping the first chamber undestroyed will be broken down into fully oxidized products.

The exhaust gases may contain a number of pollutants which must be removed before the exhaust can be emitted into the atmosphere. Some pollutants such as carbon monoxide and nitrogen oxides can be minimized by proper design and operation of the incinerator. However, others such as solid particles can not be eliminated by incinerator operation. These materials must be removed by air pollution control devices (APCDs). Solid particles are formed from inorganic material in the waste. This material includes metals dissolved in the oil and sand or grit suspended in the oil. The cleaner the oil the fewer particles that are formed and the less extensive an air cleaning system required.

Three types of devices are generally used to remove solid particles from a gas stream. These are the electrostatic precipitator, the fabric filter and the wet scrubber. A fabric filter is the most effective device of the three at removing particles. A electrostatic precipitator is the next most effective and a wet scrubber is generally the least effective (2).

Some used oils contain chlorine or sulfur. The chlorine may have been absorbed by the oil from plastic piping or containers or may have been introduced as part of an additive. The sulfur may be present in additives or may be a constituent in the original oil. If the incinerated oil contains these elements then acids may form in the exhaust gases. The acids are highly corrosive and must be removed from the gas stream. This is usually accomplished with a wet scrubber. The water absorbs the acids from the gas stream. However the acidic water must then be managed in a safe manner. Many incinerators are equipped with wet scrubbers to remove acids and an electrostatic precipitator to remove particles.



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Figure 9-1. Rotary kiln incinerator system.

The expense of building an incinerator to burn used oil can be reduced by modifying an existing device. This process is called retrofitting and varies in difficulty depending on the device to be modified and the characteristics of the oil. The modifications required by a liquid injection incinerator are relatively simple. The delivery and injection system must be modified to account for used oil properties differing from those of the original fuel. These properties include viscosity and heat content. The gas cleaning devices must be capable of removing any new contaminants introduced by combustion of the oil. Oils with high solids contents cannot be burned in liquid injection incinerators.

A rotary kiln can also be retrofitted to handle used oils. Oils with high solids contents may require no modifications. They can be introduced with solid wastes. In some cases a special nozzle known as a sludge lance is used to inject the dirty oil. Clean oils may be injected with the auxiliary fuel used to maintain temperature. In this way the heat of combustion can be used to aid in the destruction of other wastes. The waste delivery system would require modification for this type of operation.

Economic Considerations

Incinerators are considerably more expensive than flares and thus require a more thorough economic analysis. Two options exist for the treatment of used oils in incinerators.

1. Incineration in an onsite device
2. Shipment to offsite device.

Onsite incineration is a practical alternative for large quantity generators. Capital costs for typical rotary kiln incinerators average 0.5 million dollars for a small 10 million Btu per hour unit to 1.5 million dollars for a unit ten times this size (4). However this does not include the support equipment, permitting, startup and trial burn costs which can easily triple the capital outlay. Operating costs include auxiliary fuel, maintenance, system monitoring, oil analysis, water, electricity, and management of by-products such as scrubber water and captured particles. These costs are about 10 percent of the capital cost per year but vary significantly depending on the unit (4).

Current Practice

Because of the economic benefits of recycling used oils, only a small quantity is currently incinerated. The oils that are incinerated generally have high concentrations of toxic contaminants that make recycling impractical or unsafe. Less than 2 percent of the used oil collected in California in 1985 was incinerated without some effort to recover energy (1).

9.3 Combustion for Energy Utilization

One of the most common applications of recycled oils is fuel usage. Over 80 percent of the reprocessed oil produced in California was used as either a primary or supplemental fuel in 1985 (5).

9.3.1 Regulatory Considerations.

Two sets of regulations apply to the use of oils as fuels. First, all oils not meeting specifications are classified as hazardous wastes in California. Extensive regulations apply to the combustion of hazardous wastes. Second, emissions from incineration devices are regulated by federal and local statutes. The regulations specify maximum amounts of air pollutants such as carbon monoxide, ozone, nitrogen oxides, sulfur dioxide, total suspended particles and lead (6) that can be emitted into the atmosphere. Additional regulations are currently being developed to limit the emission of toxic metals and other constituents from industrial boilers burning hazardous waste (which may include used oil presumed by EPA to be mixed with listed halogenated solvent wastes) (7).

9.3.2 Technical Considerations

Reprocessed oils have been used as fuels in a number of different combustion devices, including (5):

- Ship Engines
- Kilns (may not all be high-temperature kilns)
- Furnaces (includes pipe stills, heaters, and furnaces)
- External Combustion Boilers
- Internal Combustion Engines
- Clay Dryers

In 1983 over half of all reprocessed oil fuel was used as bunker fuel oil on ships (5). It is not possible to trace this fuel any further. About half of the oil derived fuels are cofired with virgin fuels (5).

A kiln generally consists of an inclined rotating drum in which a solid material moves from one end to the other. Oil is injected at one end of the kiln in fine droplets which subsequently ignite. Air may be supplied through the same nozzle as the fuel or through adjacent nozzles. The kiln is generally maintained at high temperature. The feed and gas have relatively long residence times. The fuel may be preheated and can thus have high viscosity. Fuels best suited to kilns have little solid materials for proper injection. Fuels with high heat contents are most desirable.

External combustion boilers generate steam and electricity. Emissions from boilers burning used and waste oils have been studied by several researchers (9,10,11,12,13). Fuel and air are injected into a combustion chamber. The exhaust gases are cooled rapidly upon leaving the combustion chamber. They pass through heat exchangers which use heat from the gas stream to generate steam. Boilers vary in size from 0.5 million Btu per hour to over 100 million Btu per hour. Boilers are usually not equipped with APCDs (5). Thus, fuels must not contain dangerous materials that may end up in the exhaust. Federal regulations are currently being considered to control emissions from boilers burning hazardous used oils (7).

9.3.3 Economic Considerations

Combustion of used oils as fuels is economically favorable. Combustion results in destruction of the oils while at the same time replacing a virgin

fuel oil. All processes use combustion units designed to burn other fuels. A separate delivery system is the only requirement to burn used oil. Additional air pollution control equipment may be needed to control pollutants.

9.3.4 Current Practice

The number of devices burning used oil-derived fuels and the amount of used oil-derived fuels burned in 1983 in the various types of devices is shown in Table 9-1. Quantity of used oil-derived fuels burned onsite by industries in 1983 are shown in Table 9-2.

9.4 Conclusions and Recommendations

Combustion in unapproved or poorly performing equipment is inefficient and irresponsible. Waste oil generators should be discouraged from that. Incineration should include good incinerator design and operation. Uniform, predictable waste oil fuel properties are essential. This is enhanced by the segregation this report recommends.

Table 9-1. Verified methods of combustion of used oil-derived fuel

Combustion Unit	Volume/year (1983), gallons
Kilns (may not all be high-temperature kilns)	1,844,114
Furnaces (includes pipe stills, space heaters and furnaces)	100,945
External Combustion Boilers	45,628
Internal Combustion Engines	10,400
Clay Dryer	600
TOTAL	2,001,687

Source: Ref. (5).

Table 9-2. Verified in-house users of used oil-derived fuel

Description	Volume/year (1983), gallons
Electrical Services	41,328
Miscellaneous Nonmetallic Minerals	13,700
Paving Mixtures and Block	10,450
Lime Products	3,000
Nonclay Refractories	3,000
Ferroalloy Ores, except Vanadium	4,000
Pulp Mills	1,800
Beet Sugar	850
Fire Clay	600
Dairy Products	300
TOTAL	88,028

Source: Ref. (5).

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CHAPTER 10 BIOLOGICAL TREATMENT

Some microorganisms are capable of destroying the hydrocarbons in oil waste. A number of waste treatment systems use biological processes. Biological techniques are best suited to handling large quantities of oil waste. They are not capable of processing waste mixtures containing certain hydrocarbons or high concentrations of toxic metals. In the past, biological processes have been used primarily to pretreat oil wastes before discharge to a public sewer system.

10.1 Regulations

As discussed in Chapter 5, oil waste management is federally regulated by the EPA under jurisdiction of the Resource Conservation and Recovery Act (RCRA) and the Used Oil Recycling Act of 1980. Used oils are not currently classified as a hazardous waste by the EPA. A number of federal regulations do apply, however, if the oils are not recycled. Biological treatment processes may occasionally be used as recycling techniques. Microbes can be used, for example, to break tars down into pumpable liquids (1). However, in general the processes are used to destroy oil waste. Since most biological treatment plants are oil destruction units, they must obtain operating permits from the EPA. They are also subject to EPA's management standards and record keeping requirements.

California regulations are stricter than federal regulations. Used oils are considered a recyclable hazardous waste. Thus the state may require anyone using biological techniques to justify why they are not recycling. All systems must insure that the oil waste will not contaminate the environment. This is particularly difficult in some biologically based processes which use large surface ponds or spread oils on the ground.

One microbe based oil disposal process involves spreading oils over a tract of land. This process is called landfarming. It has come under severe criticism. Recent legislation in California has placed strict constraints on landfarming (2). Landfarming systems are now required to meet many of the same standards as landfills.

10.2 Technical Discussion

A number of microorganisms can break down hydrocarbons in oil waste into carbon dioxide, water, and other simple compounds. These microbes occur naturally and are found throughout the world. They live on land, in salt water, and in fresh water (3). Several processes have been developed to use these organisms. The processes have several benefits. First they convert oils into nontoxic gases at room temperature. Biological processes have low maintenance and operating costs. Biological systems are also inexpensive to build.

Microorganism based treatment systems can produce air pollutants. Odors are a common air quality problem for biological systems. Aerated biological treatment often air-strips volatile pollutants from the waste. Activated sludge treatment and landfarming are particularly susceptible to this. In

general, any process which exposes waste to air is a potential source of emissions from volatile components in that process. Emissions will depend on composition, conditions, and extent of air contacting. Even relatively nonvolatile materials may evaporate with sufficient air exposure. However, a modern biological treatment system has no inherent air pollution problems if properly designed and properly operated for the waste for which it was designed.

Biological processes have a number of drawbacks. They produce a bulky sludge with a high water content. Toxic substances, including heavy metals, are concentrated in this sludge. Biological treatment is slower than other management methods such as incineration. This means that for a given treatment capacity a biological system would require a much larger plant than an incinerator. A high risk of environmental contamination exists for biologically-based processes such as landfarming. This risk stems from the intimate contact between the oil and the environment. Biological processes can handle a limited range of oils. Large concentrations of heavy metals will kill the organisms. Some hydrocarbon compounds such as polychlorinated biphenyls (PCBs) are not biodegradable. Biological systems can become overloaded when processing high concentrations of hydrocarbons. Biological treatment is most effective at treating oily water. Therefore some oil wastes may have to be diluted with water before biological treatment.

In all biological treatment systems, the oil waste is kept in the presence of the organisms for long enough for complete digestion of hydrocarbons. In addition to hydrocarbons, the microbes may require oxygen and nutrients such as phosphorous and nitrogen. Thus the following factors are important:

- Residence time
- Microbe concentration
- Oxygen concentration
- Nutrient availability.

In general there are two classes of biological systems :

- Solid based systems
- Liquid based systems

10.2.1 Solid Based Systems

In solid based systems most of the mass is made up of solids. In general the solids are inert and either the oil or microbes are immobilized on the solid particles. One solid based system widely used in the past is landfarming. This process involves spreading the oil waste onto a tract of land. The soil is tilled to insure adequate aeration. It is fertilized to provide the needed nutrients. Microorganisms in the soil digest the waste. Metals become bound to the solid particles (4). The danger of environmental contamination is great and its use is being limited (2). A process similar to landfarming can be used to clean up areas in which oil wastes have been spilled or dumped. In this process, microorganisms and nutrients are pumped through the site to destroy the waste (5). However, microbes often do not distribute well and are filtered out by the soil.

A second class of solid based systems are the attached/entrapped growth (AEG) systems. In these systems a surface is provided for the microbes to grow on. Oily wastes are pumped past the surface and the attached microbes destroy the oils. The most common AEG system is the trickling filter. In this system the waste flows slowly over a bed of plastic media or rocks. Attached microbes cover the media surface. AEG systems allow the microbe colonies time to grow and adapt to the oil (6). Recently developed AEG systems use fluidized beds. Oil is pumped up from the bottom of a bed of particles on which microbes have been immobilized. The flow of oil lifts the particles apart. Low flow ensures that particles are not carried out of the reactor. Flow is very well mixed to insure that all of the waste comes in contact with microbes (7). The microbes require nutrients such as nitrogen and phosphorous as well as hydrocarbons in order to survive. If sufficient quantities of nutrients are not naturally present in the waste they must be added.

After a period of operation the microbes and the sludge they produce can clog a trickling filter. The system must then be shut down and cleaned. Typically this occurs after 50 to 100 days of operation (6). To eliminate the interruption for shutdown, cleanout, and restart, a trickling filter can be designed to continually slough off microbe growth. This requires dilution of the influent waste, with associated larger facility size. All systems, however, produce sludge. Sludge is a mixture of dead microbes, living microbes, and indigestible materials. Sludge is typically dried and disposed of in a landfill. Sludge may also be incinerated.

10.2.2 Liquid Based Systems

There are two common types of liquid based systems - aerobic and anaerobic. Aerobic systems use bacteria in the presence of oxygen. Anaerobic systems use bacteria in the absence of oxygen. The bacteria may be facultative, in that the same microbes can adapt to either aerobic or anaerobic conditions. Each condition is capable of destroying different hydrocarbons. For example, aerobic conditions are capable of digesting compounds like chlorobenzene but not compounds like chloroform. Anaerobic conditions on the other hand can digest chloroform but can not digest chlorobenzene (6).

In general, the equipment used in liquid based systems is very similar to that used in sewage treatment plants. As the used oil or oily waste enters the system, large solids are removed. Occasionally the material is also filtered to remove the smaller solids. High oil concentrations can overload the process or even kill microbes. Therefore the waste may have to be diluted. Sludge containing the microbes needed to digest the waste is then added to the liquid. Any needed nutrients are added. The mixture is then pumped to a pond where the sludge is kept suspended by constant mixing. Aerobic systems also pump air through the mixture. After the oils have been destroyed the water flows to a second pond to settle the sludge. The clarified water can be either recycled and used to dilute incoming material, or discharged into the environment. The sludge produced settles to the bottom of the pond and is collected. The sludge has high concentration of microbes as well as any indigestible materials such as toxic metals. Some of the sludge is used to provide microbes for the influent waste. The rest is land disposed or incinerated.

Variations on this basic process are used. To increase contact between microbes and oil, structures on which the microbes can grow are sometimes installed. These structures immobilize the microbes and provide even spatial distribution throughout the holding pond (8). Additional stages remove contaminants like toxic metals that are not biodegradable.

A second variation involves adding specially selected microbes to the waste in addition to those that occur naturally. This is called bioaugmentation and is an emerging technology. Microbes are selected for their ability to digest a specific hydrocarbon (9). Bioaugmentation can destroy a wider range of hydrocarbons than processes that only use naturally occurring microbes (9).

10.3 Economic Considerations.

Landfarming was at one time very inexpensive for oil waste management. However, due to recent regulations landfarming is rapidly becoming prohibitively expensive. Current legislation requires landfarming to meet many standards that landfills are required to meet (2). In the last three years the costs for land disposal units in general have increased by as much as 600 percent (10). Landfill capital costs can range from 1.3 million dollars for a 5000 ton per year unit to 1.8 million for a 15,000 ton per year unit. Annual operating costs can vary from 0.9 million dollars for the smaller unit to 1.4 million dollars for the larger unit (11). These costs are rough estimates of landfarming system costs. The costs do not include insurance and permitting, which are becoming more important. Additionally, landfarming may not destroy all hazardous materials. The generator is liable for any damage caused by the undestroyed material.

Other solid and liquid based systems are more closely controlled than landfarming and are thus safer. Many new techniques are being used in these systems based on basic ideas that have been well proven over the years in sewage treatment plants. Treatment costs can vary widely. Liquid based system capital costs can range from 137,000 dollars for a 25 gallon per minute system to 242,000 dollars for a 100 gallon per minute system. Operating costs average around 0.79 dollars per thousand gallons for the smaller system to 0.328 dollars per thousand gallons for the larger system (8). These correspond to approximately 3000 dollars per year and 1000 dollars per year respectively. Bioaugmentation systems are more expensive due to the cost of the special bacteria. Bioaugmentation can cost as much as 1.0 dollar per thousand gallons (12).

10.4 Current Practice

Land-based disposal systems are being phased out. Regulatory and economic pressures are making installation of these systems unprofitable. It is highly unlikely that any new land disposal unit will be permitted in California in the foreseeable future. While land based biological techniques may find use in site cleanup operations, they should not generally be considered a viable oil waste management alternative.

Other solid based systems and liquid based systems are more viable. Liquid based systems process used oils, oil wastes, and oily by-products from various industries. Biological techniques are widely used to pretreat oily

wastewater before discharge to a municipal sewer system. However, little oil waste is transported to offsite biological treatment plants. Currently less than one percent of the oil waste generated in California is transported to biological treatment sites (13).

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CHAPTER 11

PRETREATMENT OF OILY WASTEWATER FOR SEWER DISCHARGE

Oil-bearing wastewater contains small amounts of free, emulsified or dissolved oil. It also contains contaminants such as dirt, metals and organic compounds. Oil-bearing wastewater is generated by such activities as metalworking, vehicle and industrial equipment washing, rain runoff from equipment and parking lots, development of bilge and ballast in ships, and spills and leaks occurring during the transportation of used oils. The largest industrial oily wastewater generators are waste oil rerefiners, petroleum refiners, waste oil haulers, crude oil producers, and operators of cresylic acid extraction processes for oil wastes (1). If a company generates oily wastewater, then sewer discharge is often the simplest and most economical management method. Using existing sewer systems can minimize disposal costs. Because industrial oily wastewater often contains contaminant levels exceeding sewer capabilities, pretreatment is frequently necessary prior to sewer discharge.

11.1 Pretreatment Regulatory Review

Sewer discharge pretreatment regulations are enforced under authority of the Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251), as amended by the Clean Water Act of 1977 (Pub. L. 95-217). The Clean Water Act established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." The portions of the act specifically dealing with pretreatment are Sections 307(b) and 307(c), which require the U.S. EPA to establish pretreatment standards for industrial sources, and Section 402(b)(8), which states that National Pollutant Discharge Elimination System (NPDES) permits issued to publicly owned treatment works (POTWs) must include requirements for pretreatment programs.

As a result, EPA established the National Pretreatment Program to protect municipal wastewater treatment plants and the environment from the damage that may occur when hazardous or toxic wastes are discharged into a sewage system. This protection is achieved by regulating industrial or nondomestic users of a publicly owned treatment works (POTW) who discharge toxic wastes or unusually strong conventional wastes.

The four major problems that can be prevented through implementation of a local pretreatment program are:

1. Interference with POTW operations.
2. Pass through of pollutants to receiving waters.
3. Contamination of municipal sludge.
4. Exposure of POTW workers to chemical hazards.

EPA has developed pretreatment regulations which consist of a two-tiered regulatory strategy for implementing the National Pretreatment Program. The first tier consists of general pretreatment regulations that provide

administrative, legal, procedural, and technical guidelines for (a) local POTW programs designed to control toxic discharges to municipal treatment plants, and (b) the State program to review, approve, and oversee the local POTW programs.

The second tier of the National Pretreatment Program provides for (a) national prohibited discharge standards which forbid certain types of discharges by any sewage system user, and (b) technology-based pretreatment standards that apply primarily to toxic wastes discharged to municipal sewer systems from 27 categories of industrial users (IUs). The technology-based pretreatment "categorical" standards are applied as minimum limits for all categorical IUs discharging to municipal systems and are codified in 40 CFR, Subchapter N, Effluent Guidelines and Standards. A POTW is required to establish "local limits" for site-specific conditions to prevent interference, pass through, sludge contamination, and worker health and safety problems due to toxic discharges. These local limits apply to all IUs, including the categorical IUs if the local limits are more stringent than the Federal categorical standards.

On February 7, 1986, EPA submitted a report to Congress concerning wastes discharged into municipal sewage systems. This report, commonly referred to as the "Domestic Sewage Study", examined the nature and sources of hazardous wastes discharged to POTWs, measured the effectiveness of EPA programs in dealing with such dischargers, and recommended ways to improve the programs to achieve better control of hazardous wastes entering POTWs. The Domestic Sewage Study concluded that the National Pretreatment Program as established within authorities of the Federal Clean Water Act generally provides the best method of controlling hazardous waste discharges to POTWs, as opposed to authorities provided in the Federal Resource Conservation and Recovery Act (RCRA). However, the Domestic Sewage Study concluded that the National Pretreatment Program should be more broadly and effectively employed to regulate these discharges. As a result, EPA is revising and adding to its pretreatment regulations to ensure that hazardous wastes discharged to POTWs are adequately controlled to protect human health and the environment and to bring the National Pretreatment Program into parity with other hazardous waste management programs.

In summary, the U.S. EPA has promulgated pretreatment standards for the major categories of industry. Under the new standards, states are responsible for administering pretreatment programs for POTWs that do not have their own programs. The regulations limit the discharge of corrosive, hazardous, and toxic substances. Other substances, such as oils and suspended solids, have limitations imposed upon them by POTWs to avoid overloads.

11.2 Composition of Oily Wastewater

Oily wastewater composition varies widely depending on the generation process. Pollutants include organic matter, inorganic salts, acids, bases, heavy metals, and microorganisms. Pollutants can exist in dissolved, suspended, or floating states.

Pollutants can be divided into two categories. The first category consists of toxic pollutants. These substances are toxic to sewer bacteria. They

reduce treatment plant efficiency. Materials in this category include heavy metals and organic substances such as cyanides and phenols. This category includes substances that pass through the sewer system untreated and become concentrated in the sludge or effluent water, such as chlorinated organic compounds.

The second category of pollutants consists of high-strength organic wastes. These wastes can be handled by POTWs. However, due to their high concentration they place an increased burden on the POTW. Included in this category are oils and suspended organic solids. A POTW can require that high-strength organic wastes be removed using pretreatment processes. Alternatively, the POTW can impose a surcharge to cover increased treatment costs. For floating oils, this surcharge typically ranges from 2.5 to 20.0 cents/lb (2).

11.3 Sewer Capabilities and Limitations

Sewer system efficiency decreases as contaminant concentration. Table 11-1 lists inhibitory contaminant concentrations, as well as suggested pretreatment methods. Treatment plants can generally handle oil up to a concentration of about 125 mg/l. Excess oil can present the following problems (2):

1. Inhibition of biological process
2. Clogging of screens
3. Interference with skimming
4. Fouling of float systems and electrodes
5. Development of fire and explosion hazard

Excessively high or low pH can corrode pipes and pumping equipment, and thus permanently damage a treatment system. Heavy metals can poison bacteria and inhibit biological treatment efficiency. Chlorides can pass through the system untreated and cause environmental problems. Therefore, effective pretreatment is necessary for sewer systems to function properly.

11.4 Wastewater Pretreatment Processes

11.4.1 Neutralization

Excessively high or low pH can reduce biological efficiency, corrode sewer components, and endanger sewer workers. If an industrial wastewater system has a time-averaged pH that is nearly neutral but is prone to pH spikes or suddenly shock loads, equalization chambers can be used to adjust pH. Equalization chambers are large holding tanks that provide wastewater with long enough residence time to dampen pH spikes.

If pH is consistently high or low, then chemical neutralization may be required. Simple neutralization systems allow the water to flow over beds of limestone or other neutralizing agents. More sophisticated systems contain continuous pH monitors and automatic chemical dispensers.

Table 11-1. Inhibitory Concentrations of Constituents Discharged to POTWS

Constituent	Limiting or Inhibitory Concentration	Pretreatment Method
Oil or grease	125 mg/l	Lagooning, sedimentation, flotation
Suspended solids	50 mg/l	Skimming tank or separator
Heavy Metals	1-10 mg/l	Precipitation or ion exchange
Alkalinity	0.5 lbs alkalinity as CaCO ₃ /lb BOD removed	Neutralization
Acidity	Free mineral acidity	Neutralization
Sulfides	100 mg/l	Precipitation or stripping
Chlorides	8000-1500 mg/l	Dilution, deionization
Phenols	70-160 mg/l	Stripping, complete mixing
Ammonia	1600 mg/l	pH adjustment and stripping, dilution
Dissolved salts	16,000 mg/l	Dilution, ion exchange

Source: Ref. (6).

11.4.2 Oil Removal

When oil is present in concentrations above 125 mg/l, it generally cannot be handled by sewer systems and must be removed. Oils can exist in free, emulsified, or dissolved states. Figure 11-1 shows oil droplet size classification and typical removal methods. Gravitational separators are most commonly used for removal of free oil. The three most popular types of gravitational separators are American Petroleum Institute (API), corrugated plate interceptor (CPI), and parallel plate interceptor (PPI) separators. In each of these devices water is maintained in a quiescent state, allowing oil to rise to the top, where it is skimmed off. Gravitational separators are inexpensive and simple to operate. However, they have limited efficiency and can not remove dissolved or emulsified oil. Gravitational separators can generally remove oil down to a concentration of 100 to 200 mg/l. CPI and PPI separators are more efficient than API separators because they have more plate area over which the water can flow (4,5).

When oil is emulsified, the emulsion must be broken before the oil can be efficiently removed. Emulsions are broken by adding chemicals or changing pH. Alum, lime, and polyelectrolytes are commonly used chemicals. Polyelectrolytes are the most efficient and generate the least amount of sludge. However, they are also the most expensive.

Air flotation is frequently used to remove oils after emulsions have been broken. The two most common types of air flotation devices are dissolved air flotation (DAF) and induced air flotation (IAF) units. Air bubbles carry oil to the surface of the water, where it is skimmed off. Solids are also carried to the top and removed. Air flotation units are reliable and are able to handle shock loads of oil.

Dissolved oil is most difficult to remove. The most commonly used methods dissolved oil removal are carbon adsorption and biological treatment. Carbon adsorption utilizes the natural tendency of oil to adhere to the surface of carbon particles. Carbon particles used for adsorption have high ratios of surface area to volume. Carbon adsorption is highly efficient and requires little area for equipment. However, it is also expensive and energy intensive. It also requires regeneration of used carbon particles.

Biological treatment processes utilize microorganisms to decompose hydrocarbons. Commonly used biological treatment systems include fluidized bed, trickling filter, rotating biological contactor and activated sludge systems. Wastewater flows through or across a medium that is inhabited by bacteria. Oil and other organic compounds are digested. Biological systems can be highly efficient. However, they can be damaged by toxic contaminants and destroy oil rather than recycling it.

11.4.3 Treatment of Toxic Materials

The two toxic materials of greatest concern in wastewater are heavy metals and toxic organic compounds. Heavy metals have the potential to both harm sewer systems and pose environmental problems if they pass through to the environment. Techniques commonly used to remove metals include reverse osmosis, ion exchange, and chemical precipitation. Reverse osmosis utilizes osmotic pressure to remove metal salts during high-pressure filtration

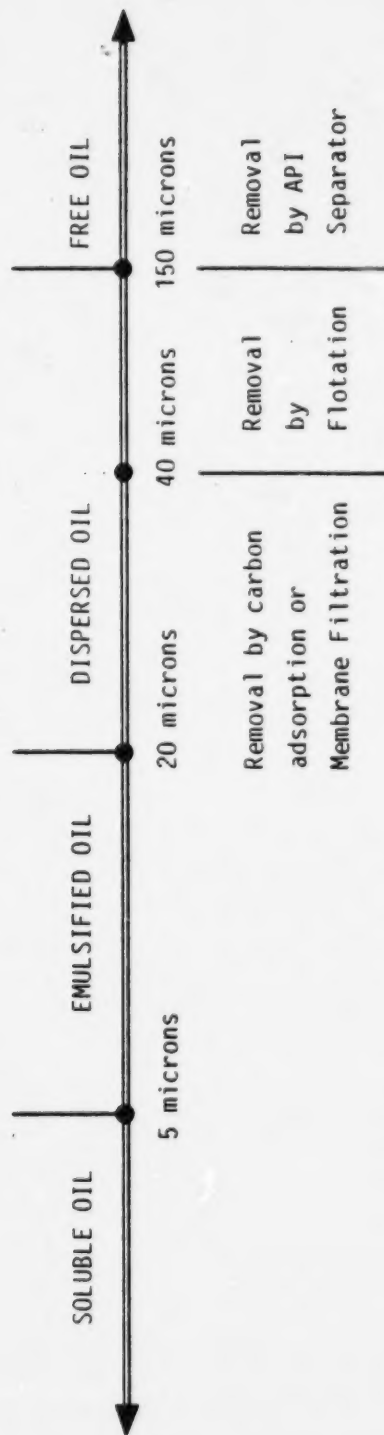


Figure 11-1. Classification and size range of oil droplets source: Ref. (3).

through a semipermeable membrane. The process produces purified water and concentrated metal salt solution. Ion exchange uses cation and anion resins to capture metals. It is most effective when applied to dilute waste streams. Chemical precipitation reduces metals using sodium borohydride or sodium meta bisulfate. Subsequent reaction with sodium hydroxide precipitates out metals.

Organic contaminants can also damage sewers and the environment. These contaminants include chlorinated compounds, phenols, and benzene compounds. Carbon adsorption and biological treatment are often used to remove organic contaminants. The principals are the same as those described in Section 11.4.2 for oil removal. Stripping and UV/ozone oxidation are also frequently used. In stripping, the wastewater stream contacts a stream of air or steam. Contaminants are transferred to the gas. In UV/ozone oxidation, the wastewater is contacted with ozone in the presence of ultraviolet (UV) light. This achieves high oxidation efficiency.

11.4.4 Solids Removal

Solids are generally removed mechanically. Chemical coagulants and flocculants are often first added to increase particle size. Devices commonly used for solids separation include sedimentation chambers, liquid cyclones, coalescers and filters. Sedimentation chambers are tanks that provide water enough residence time to allow particles to settle and be removed. Liquid cyclones use inertial properties to separate particles from water as the water spins through a cylindrically shaped device. Coalescers provide surfaces on which oil droplets collect and grow, allowing them to be easily collected. Filters are porous media through which water passes, depositing collected particles on the media surface. All of these mechanical collectors are relatively efficient and inexpensive. However, they generate waste sludge that must be managed.

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CHAPTER 12

EMERGING TECHNOLOGIES AND ALTERNATIVES

12.1 Supercritical Water Oxidation

A recent paper by Modell (1) discusses use of supercritical water for the oxidation of organic materials. Above its critical temperature, 374 °C, and pressure, 3200 psi, water is an excellent solvent for organic matter and air or oxygen. A homogeneous system can be formed with an oxidant, oxidizable waste, and water. Reaction rates for waste destruction are very high. At 400 to 450 °C conversion is 99 to 99.9 percent in 5 minutes. At 600 to 650 °C conversion of 99.9999 percent can be achieved in less than one minute. The products are carbon dioxide, water, and inorganic salts of acid-forming elements in the feed. There are two applications of this technology under development. The first is the Modar Process (2). This is a surface treatment process for oxidation of organic wastes or aqueous wastes with 1 to 30 percent organics. The second is the Oxidyne Process (3). This is a downhole process for oxidation of aqueous wastes with approximately 1 percent organics. These processes are essentially clean aqueous incineration processes using the waste energy content to generate the needed heat and power. They are described in more detail below.

12.1.1 Modar Process

In the Modar Process the aqueous waste stream and air are fed at high pressure and ambient temperature to an oxidizer vessel. They are heated to oxidizing conditions by mixing with a recycle stream from the oxidizer vessel. Figure 12-1 is the flow sheet from reference (1). Inorganic salts dissolved in the original feed precipitate out in the oxidizer. They are removed from the oxidizer effluent using a cyclone. Part of the cyclone fluid effluent is recycled to generate the supercritical conditions at the oxidizer inlet. The rest is cooled to subcritical conditions in a heat exchanger which generates process steam. At subcritical conditions a gas phase comprising all nitrogen from the air and most of the carbon dioxide from the oxidation separates from the liquid phase. The liquid phase is water containing carbon dioxide. The two phases are separated in a high pressure liquid-vapor separator. The vapor phase is expanded through a turbine for power recovery. Some power is used for inlet air compression. The liquid phase is expanded into a low pressure separator. This releases dissolved carbon dioxide and generates clean water. The released carbon dioxide is vented to the gas turbine effluent. Sulfur, nitrogen, and phosphorus present in the feed as organic compounds are oxidized to inorganic acids. They are scavenged as salts by addition of caustic to the feed. No commercial plants have yet been built, so costs and long term operating problems have not been defined. However, a pilot plant was operated at CECOS International (4). Modar estimates (1) that a 10 ton per day plant can process waste with 10 percent organics for \$2.38 per gallon of organic or \$0.26 per gallon of waste. Extrapolation of these data by Modell (1) shows that operating cost might be as low as \$0.14 per gallon of waste for a 100 ton per day plant. Costs vary with the quality and concentration of organics in the feed and location of the plant. Another estimated range of operating costs for the Modar Process is \$0.40 to \$1.10 per gallon (4).

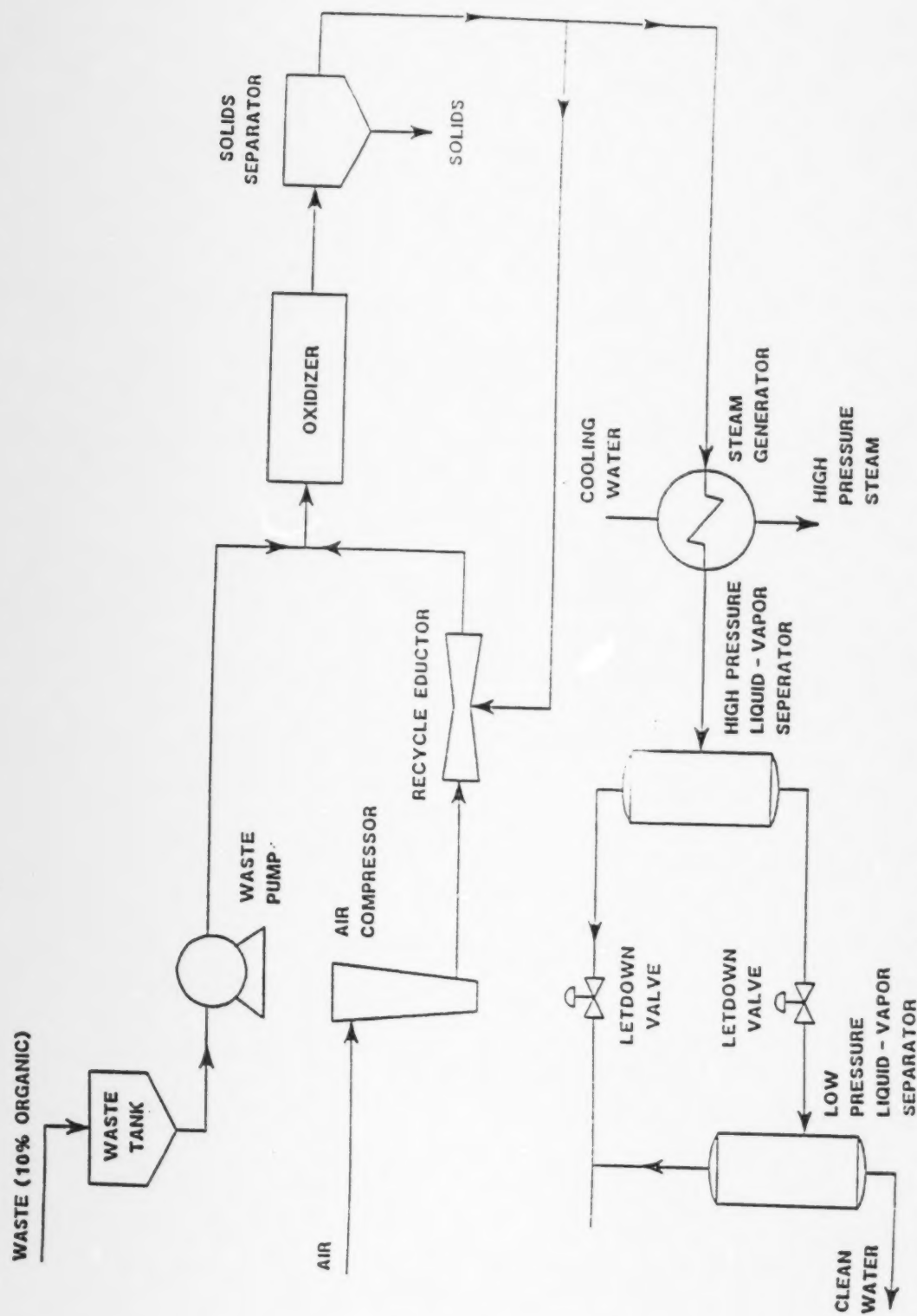


Figure 12-1. Process schematic for oxidation of an aqueous waste using the Modar process.

This is about 30 cents per gallon less than incineration. There is still some question as to the real costs of this technique.

12.1.2 The Oxidyne Process

Oxidyne performs supercritical water oxidation in reactors placed underground in deep well cavities (1). The process has been referred to as "downhole" oxidation. It is well suited to large flow rates of dilute aqueous wastes. A process flow sheet is given as Figure 12-2. The system consists of three concentric annular pipes. The outer two pipes serve as a reactor-heat exchanger system. They use the heat of the organic oxidation reaction to preheat the feed. The central pipe carries oxygen used to oxidize organics down to the level at which reaction can be sustained by the supercritical temperature of the waste. At this point the oxygen pipe terminates and the oxygen and waste are mixed in the waste feed pipe. This is usually between 3,000 and 10,000 feet down the hole. After oxygen and waste mix, the mixture continues down the waste pipe reactor for sufficient distance to permit the required residence time for reaction. Time required is usually one to five minutes. At the bottom of the reactor, the flow is reversed as the mixture enters the outer annulus of the heat exchanger. The stream is cooled on its way to the surface while preheating the feed.

The cooled effluent from the downhole reactor is depressured into a liquid-vapor separator. The liquid phase is recirculated at ambient temperature through a solids growth tank. This provides residence time for inorganic oxides and ash to agglomerate. The final step is liquid-solid separation using hydroclones and centrifuges.

The Oxidyne Process has lower temperature, less than 450 °C, and requires longer residence time than the Modar process. The downhole process requires 1 to 5 minutes for 99 to 99.9 percent destruction efficiency. In addition, the downhole process does not precipitate inorganic salts in the reactor. Additional growth volume must be provided to the liquid phase to make the inorganics removable.

Downhole processing cost projections are at a preliminary stage. They are expected to be about the same as the Modar Process in the region of small plants where they can be compared. Costs are estimated to be about 13 cents per gallon in a 100 ton per day plant (5). This is not much more expensive than the cost of the current practice of deep well injection. The downhole process has the advantage of destroying the waste.

12.2 Zimpro Wet Air Oxidation Process

The Zimpro wet air oxidation process is a subcritical process. However, it has been tested industrially in over 100 industrial plants built for specific waste applications. The first commercial waste treatment plant started operation in January, 1986 at Casmalia Resources in Casmalia, California. It was been a qualified success (6). The plant processed more than two million gallons per year of liquid wastes from 75 Southern California industries, laboratories, institutions, and defense installations. The plant was virtually booked solid at an average fee of 75 cents per gallon.

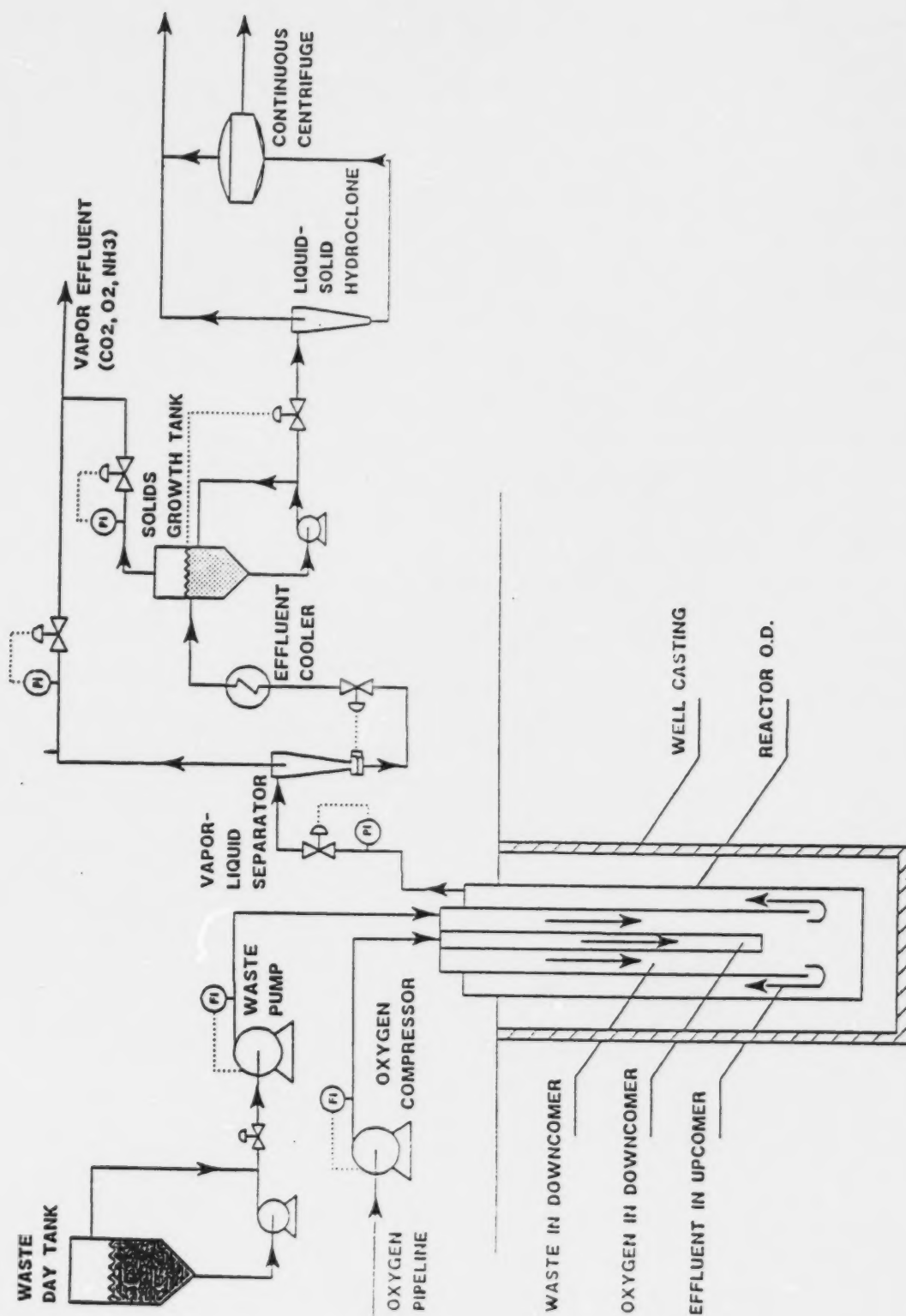


Figure 12-2. Downhole oxidation of dilute aqueous waste.

Casmalia Resources has recently ceased operation of the Zimpro wet oxidation unit. The local air district denied the facility a permit to operate the unit for failure to meet air emission standards. Zimpro Inc. acknowledged that the Casmalia unit's performance was moderate, with about 80 percent efficiency, when treating solvent still bottoms and general organics (8). During treatment, VOCs are "partially" stripped from the waste and some are emitted with the off gas. Zimpro said that the off gas emission problem can be corrected by an afterburner. This add-on device will be used when the wet oxidation unit is reinstalled in late 1988 at a new facility in Southern California.

Zimpro wet oxidation plants generally operate in the liquid phase at 220 to 350 °C and 1,000 to 2,000 psi. A flow sheet from reference (6) is given as Figure 12-3. The waste feed and compressed air are fed to an above-ground oxidation reaction vessel. The effluent from the reactor is depressured through a heat exchanger which preheats the liquid feed. Effluent is then fed to a gas-liquid separator. The gas stream is mainly carbon dioxide, nitrogen, and steam. The liquid phase is mainly water with traces of unconverted wastes. Conversion efficiency is usually better than 99.5 percent for phenols, cyanides, and pesticides. The final oxidized liquid is then sent to a biodegradation pond. This cleans up the last traces of contaminants before disposal.

Some wastes may not contain enough organic matter to provide sufficient heat to run the process. Therefore, additional hot oil heat exchange is available for the liquid feed stream. A cooler is also provided to cool the final liquid product to ambient temperature.

The Zimpro process has proved effective with phenols, cyanides, organic and inorganic sulfides, pesticides, solvent still bottoms, and organic wastewaters. The fee of 75 cents per gallon for a 6,500 gallon per day plant is high compared to the 10 cents per gallon claimed by Modell for supercritical oxidation. However, it is difficult to estimate Casmalia's true costs and the costs of industrial scale supercritical processes.

12.3 B.E.S.T. Process—Basic Extraction Sludge Treatment

The B.E.S.T. Process for sludge treatment was developed and patented by the Resources Conservation Company. A prototype was developed in the mid-1970s (7). A process flow diagram is given as Figure 12-4. A full scale transportable unit recently cleaned up 3,700 cubic yards of acidic, oily, PCB-contaminated sludges at a Superfund site in Georgia. This was the first full scale use of the B.E.S.T. process.

The B.E.S.T. process uses the inverse miscibility properties of aliphatic amines such as triethylamine to break down suspensions and emulsions in sludges and contaminated soils. The process treats wet, oily, solid wastes with an amine-water mixture at 40 °F (4 °C). At this temperature the liquids are soluble and suspensions and emulsions are essentially eliminated. Solids are removed by centrifugation. They include heavy metals precipitated as hydrated oxides due to the basicity of the amine solution. The solids cake goes to an enclosed, indirectly heated dryer. In the dryer solvent vapors are driven off, condensed, and reused. Dried solids typically contain more than 99 percent solid matter.

WET AIR OXIDATION

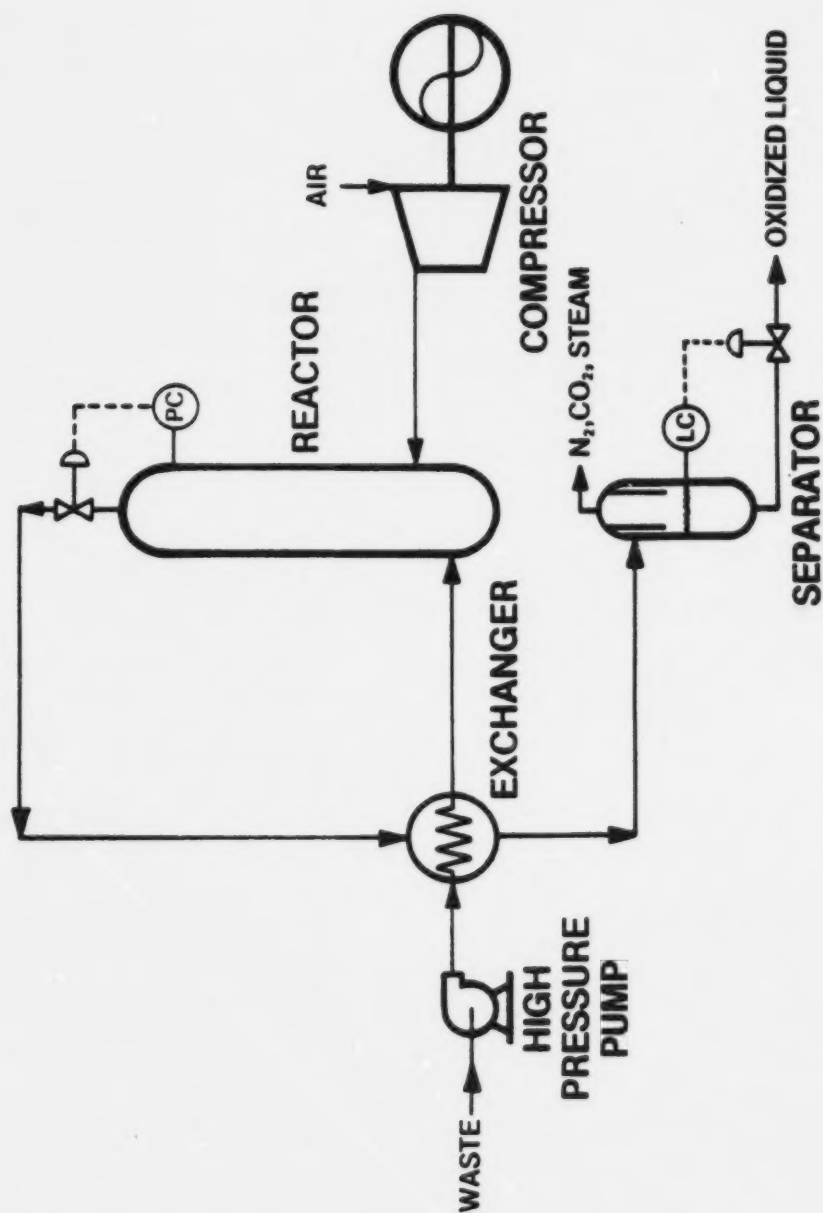


Figure 12-3. Process schematic for wet air oxidation.

The liquid fraction from the centrifuge is heated to 130 °F (54 °C). It is fed to a decanter where it splits into two phases. One phase is essentially water and the other is the amine/oil mixture. The amine/oil phase is taken off the top of the decanter. It is pumped to an evaporator or distillation unit for amine recovery. The oil in the distillation bottoms has not been chemically altered by the process and may be a usable product.

The water phase from the bottom of the decanter is pumped to a stripping column for solvent recovery. It can then be discharged to a wastewater treatment system.

The B.E.S.T. Process has been tested in a 100 ton per day transportable unit at the General Refining Superfund site near Savannah, GA. It was used on acidic, oily, PCB-contaminated sludges. The test was very successful and the process can be considered a proven technology. It is applicable to sludges from refineries, petrochemical plants, wood treating operations, wastewater treatment systems, steel mills, and other facilities generating hazardous sludges.

Costs for the B.E.S.T. Process vary widely from one application to another. Cost is affected by feed composition and variability, product requirements, utility costs and availability, and feed flow rate and volume. The total cost per ton of wet feed varies as follows:

- \$50/ton Owner operated on continuously generated, large volume, low organic sludge in a large, integrated industrial facility
- \$150/ton Resources Conservation owned and operated on a stand alone basis at a Superfund site.

These costs are less than those for incineration or regulated land disposal.

12.4 Conclusions and Recommendations

As with gaseous combustion in incinerators, combustion and oxidation in the aqueous phase wet air oxidation processes are not 100% efficient. The potential exists for total destruction of organic wastes using supercritical water oxidation. However, economics and practical design limit efficiency for some applications.

Refinements are improving the performance and economics of the above emerging technologies and variations of them. Competing systems will also emerge to displace established waste management systems having undesirable impacts. Generators should be continually observant for new opportunities to minimize the liabilities and costs of hazardous waste management.

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CHAPTER 13

IMPACTS AND TRENDS IN OIL WASTE MANAGEMENT

Oil waste management can cause environmental, economic and technological impacts. Oil prices, technological innovations, environmental concerns, and regulatory developments can all greatly affect management. This chapter summarizes recent trends in oil waste management, as well as the impacts of these trends.

13.1 Environmental Impacts

Oil waste is generated in large quantities and can impact the land, water, and air. Due to traditional land disposal methods, land impacts are of the most concern. Many recycling techniques, most notably the acid-clay method, generate waste by-products requiring land disposal. Incineration generates ash. Biological treatment generates waste sludge. These materials contain high levels of heavy metals and are classified as hazardous wastes. They can leach into ground and surface water and endanger plants and animals. Many contaminated sites containing oily waste sludges are now being cleaned up under authority of Superfund. Due to environmental problems, management methods that generate waste by-products are rapidly falling into disfavor.

In addition to regulated management, uncontrolled dumping and landfilling of oil waste can pose significant environmental problems. Approximately 76 million gallons per year of used oil is generated but not reused or recycled. This oil is assumed to enter the environment. By entering municipal landfills, storm drains, and residential back yards, this oil has the potential to contaminate the land and water. The impacts of uncontrolled dumping are not well understood, and this is an area in which future study would be valuable.

As mentioned in Chapter 9, the major area of potential air impact is used oil combustion. Uncontrolled flaring emits large quantities of pollutants. However, this is a technique that is virtually unused in California. Combustion for waste destruction or energy recovery generates fly ash and pollutants such as sulfur oxides and nitrogen oxides. However, industrial incineration devices are generally equipped with air pollution control devices. Hazardous air emissions are minimal. Additionally, since burning of used oil with contaminant concentrations over the standards is prohibited by DHS, there is little use as industrial fuels.

13.2 Effects of Oil Prices on Management Practices

13.2.1 Virgin Oil Price Fluctuations

Changing virgin oil prices can directly effect the used oil recycling industry. Crude oil prices have fluctuated from \$10 to \$30 per barrel over the last ten years. With the dramatic fall of crude oil prices in the last few years, petroleum product prices have fallen. Figure 13-1 shows a comparison of crude and waste oil prices.

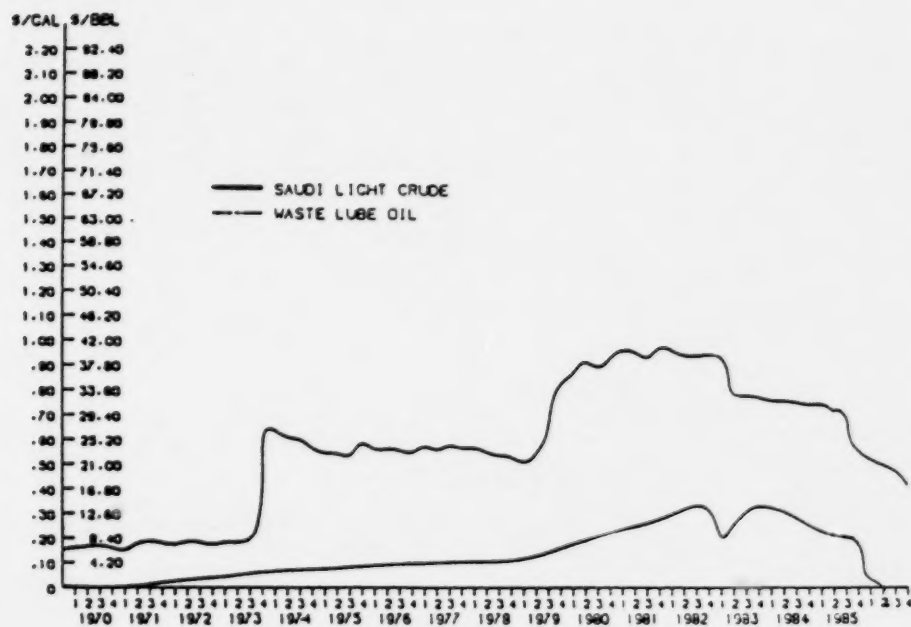


Figure 13-1. Comparison of Saudi light crude and waste lube oil prices.

Gasoline and fuel oil prices track crude oil prices very closely. When crude oil prices rise, fuel oil costs increase. When crude prices oil drop, fuel oil becomes cheaper.

Lubricating oil prices also track crude oil prices. However, they are not very price elastic. Changing crude oil prices do not necessarily lead to changing lubricating oil prices. Lube oil contains additives and other components that add to the final product cost. Lube oil production is more expensive than fuel oil production. Therefore, lube oils react very slowly to changes in crude oil prices.

13.2.2 Effect of Prices on Management Practices

A drop in crude oil price decreases the value of reprocessed oil sold as a fuel supplement. This means that used oil reprocessors receive less for their recycled oil fuel. Lower prices are then paid to transporters for used oil feedstock. Lower feedstock prices reduce the transporter's income. This can result in higher fees charged to the generator.

Changes in crude oil price do not immediately effect the rerefined lube oil market. Drops in lube oil wholesale price lower rerefiners' revenues. Rerefiners have higher fixed costs than reprocessors. They must compete with reprocessors for a steady supply of feedstock. Therefore, crude oil prices drops cause rerefiners to lose more money than reprocessors.

Low crude oil prices do not directly effect landfilling practices. However, higher transportation and recycling costs may lead to more oil waste dumping.

Low crude oil prices make virgin replacement oils less expensive. This lower replacement cost can discourage generators from investigating recycling methods.

High virgin fuel prices can encourage the illegal use of unprocessed used oil as fuel. Generators can save money by reducing fuel costs. They can also avoid paying transportation fees. However, they face potential legal penalties and are responsible for any adverse consequences of their actions.

Oil waste management costs should be reduced when virgin oil prices increase. Higher oil product prices encourage recyclers to find new feedstock sources, including sources that were not economical when recycled oil prices were low.

13.2.3 Other Factors

Virgin oil price is only one component affecting recycling operational costs. Other factors having major impacts are regulatory compliance costs, insurance premium costs, annual facility and permitting fees, and initial capital costs. Many of these factors are fixed operating costs and do not vary with virgin oil prices. Thus, while a change in virgin oil price may lead to a change in recycled oil value, recycler operating costs may not change significantly. A drop in virgin oil price lowers recyclers revenues without reducing their costs.

13.2.4 Impact of Insurance Availability and Insurance Requirements on Used Oil Management

Insurance requirements for generators, transporters, and recyclers protect human health and the environment from accidental or intentional oil waste pollution. Used oil haulers are currently required to maintain \$1.2 million of insurance coverage for sudden and accidental pollution losses. Transfer, storage, reprocessing, and rerefining facilities must have pollution liability coverage of \$1 million per occurrence, and \$2 million total for each site.

Most haulers have the auto insurance required by DHS to obtain hazardous waste hauler registration. Generators should request their transporter to provide them with proof of insurance.

13.3 Recommendations for Waste Minimization and Land Disposal Phase Out

Waste minimization refers to controlling the amount of waste requiring offsite management. Waste minimization encompasses source reduction, recycling, and waste treatment. Land disposal, traditionally the favored hazardous waste disposal option, is currently subject to ever-increasing cost and regulation. Therefore, many generators are trying to decrease the quantities of wastes generated and to improve their manageability. Waste minimization can be used by both large-scale industrial generators and small-scale individual generators.

13.3.1 Description of Waste Minimization

The three components of waste minimization are source reduction, recycling, and treatment. Figure 13-2 is a diagram demonstrating different aspects of waste minimization. Source reduction is the most environmentally preferable alternative. As discussed in Section 4.1, the two elements of source reduction are product substitution and source control. Product substitution refers to the replacement of oils by more manageable or recyclable substances. An example of product substitution is replacement of an oil-based machining fluid by a water-based fluid. Source control relates to in-plant activities. It includes alterations in technology and operating practices (1). An example of source control is a truck fleet changing oil filters more frequently rather than changing oil. Source control also includes waste stream segregation.

Recycling is the second element of waste minimization. Recycling creates a valuable product out of waste and reduces the need for land disposal. On-site recycling eliminates hazardous waste handling insurance costs and liability issues. Recycling should always be considered prior to disposal.

The final component of waste minimization is treatment. Treatment reduces waste volume and toxicity. It is needed when a waste has high water content or is contaminated by metals, solids, or organic compounds that make the oil nonrecyclable. Treatment techniques include incineration and biological treatment. Incineration destroys organic compounds and concentrates other hazardous materials in the ash. This ash then requires disposal, but has much less volume than the original waste. Biological treatment utilizes

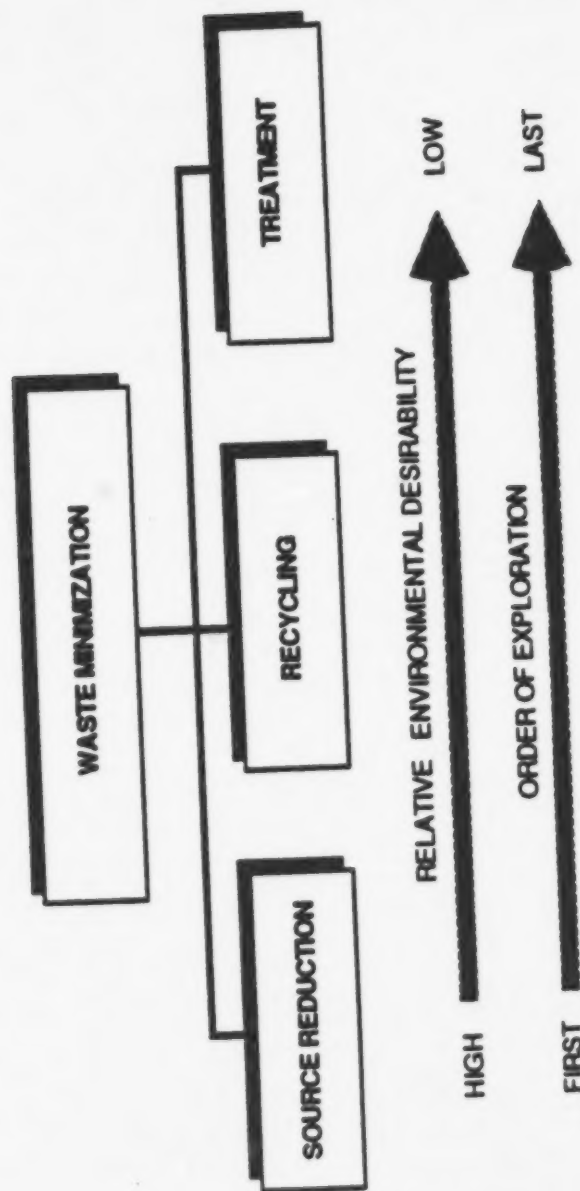


Figure 13-2. Aspects of used oil minimization. Source: Ref. 4.

microorganisms to break down organic compounds. A sludge is produced that requires disposal, but again it has much less volume and toxicity than the original waste.

13.3.2 Goals and Incentives for Waste Minimization

One goal of minimization is to decrease oil waste generation in order to decrease reliance on land disposal. Land disposal is becoming increasingly expensive and is of extremely limited capacity in California. Generators maintain liability for wastes after land disposal. In addition, with potential problems of soil and water contamination, land disposal is environmentally unsound.

Used oil generators are obligated by law to minimize hazardous waste generation. Under the Hazardous and Solid Waste Amendments of 1984 (HSWA), generators must certify on each hazardous waste manifest that they have "a program in place to reduce the volume or quantity and toxicity of waste to the degree determined by the generator to be economically practicable" [HSWA Section 224(b) (1)]. The EPA has not, however, given generators much guidance as to what efforts constitute a valid waste minimization program (2). In addition to existing regulation, there is the prospect of stricter legislation in the future. The EPA is scheduled to reevaluate industry's efforts to minimize wastes in 1990 (3).

Another strong incentive for waste minimization is that it can be economical. Source reduction can decrease need for new materials and decrease waste handling costs. Treatment can reduce waste volume and toxicity. Minimization can also decrease liability and insurance costs incurred by hazardous waste handling. Waste minimization programs have proven in most cases to be cost efficient. A survey of 28 published waste minimization cases revealed that over 80 percent of the cases had payback periods of less than 3 years, which is the period indicative of high profitability (4).

13.3.3 Technical Recommendations for Used Oil Minimization

Extending oil life, substituting more manageable fluids, and improving management techniques can be used to minimize oil waste. Figure 13-3 is a checklist of waste minimization methods. Oil life extension is both technically and economically attractive. For example, metalworking oils become unusable when contaminated by water, dirt, or tramp oils. Simple gravity settling systems can remove impurities and extend life. Similarly, transformer oils can become unusable when they contact contaminants such as water and begin to oxidize. Properly sealing oil containers can minimize oxidation and extend life.

Substitution of oils can also minimize generation. Some chlorinated solvents can be replaced by nonchlorinated hydrocarbon solvents. This improves the recyclability of oils contacted by these solvents. Oils containing additives that diminish recyclability can often be replaced by pure oils. Use of surfactants should be avoided. Surfactants cause oils to form emulsions in water, which makes them difficult to separate.

Process element	Options to investigate	Options to investigate
Materials	☐ Buy higher-purity raw materials ☐ Switch to less-toxic raw materials ☐ Use noncorrosive raw materials	☐ Employ efficient washing and rinsing methods ☐ Eliminate the use of filter aids ☐ Adopt countercurrent washing ☐ Recycle spent washwater
Operating practices	☐ Tighten equipment inspection and maintenance ☐ Improve operator training ☐ Provide closer supervision of personnel ☐ Practice better housekeeping ☐ Employ better process-monitoring systems ☐ Improve quality control	Leaks and spills ☐ Employ bellows-sealed valves ☐ Specify pumps with double mechanical seals, or canned (sealless) ones ☐ Maximize use of welded, instead of flanged, pipe joints ☐ Curtail water use for spill cleanup
Materials handling	☐ Segregate containers by prior contents ☐ Use washable/recyclable drums ☐ Buy materials in bulk or larger containers ☐ Purchase materials in preweighed packages ☐ Employ pipelines for intermediate transfer	Equipment-cleaning ☐ Use corrosion-resistant materials ☐ Convert from batch to continuous processing ☐ Alter production schedule to minimize the number of cleanings ☐ Increase equipment-drainage time ☐ Agitate storage tanks
Reaction/processing	☐ Optimize the reactor design and reaction conditions ☐ Optimize the reactant-addition method ☐ Eliminate the use of toxic catalysts	☐ Use mechanical wipers on mix tanks ☐ Clean mix tanks immediately after use ☐ Install a high-pressure spray-wash system ☐ Adopt a countercurrent rinse sequence ☐ Re-examine the need for chemical cleaning ☐ Use in-process cleaning devices ☐ Recycle spent rinsewater ☐ Blanket with nitrogen to reduce oxidation

Figure 13-3. Waste minimization checklist. Source: Ref. 3.

Improving management techniques can also minimize the generation. Spills should be cleaned using dry techniques, such as "Oil-dry," rather than water sprays, which generate wastewater. Segregation of used oils from solvents and water streams improves manageability. Clearly labeled containers can assist in segregation.

13.3.4 Elements of Successful Waste Minimization Programs

The first element of a successful minimization program is management commitment. Minimization programs often encounter resistance from plant personnel (5). Enthusiastic endorsement by management is often required to help employees overcome the opinion that established processes cannot be improved. In addition, when used with pieces of machinery costing thousands or tens of thousands of dollars, oil is justifiably perceived as cheap and expendable. Therefore, personnel must be taught that waste minimization programs can be implemented without endangering equipment or sacrificing product quality. Management must convince personnel that waste minimization and pollution control are important parts of their jobs (5).

After a commitment has been made by the company, the next element of a minimization program is problem definition. This can effectively be done with a waste audit (3,4,6). The audit defines the existing process and suggests improvements. The first step of the audit is initiation, in which goals are defined and organization is established. The next step is the pre-audit planning, in which an inspection agenda is prepared, plant data is compiled, and target waste streams are selected. The next step is the audit inspection. This is a tour of the plant during which used oil generation sources, housekeeping practices, oil spills and leaks, and cleanup practices are observed. The next phase of the audit is compilation and evaluation of options. Technical and economic feasibility studies are done to assess minimization options. Factors to be considered include technical soundness, effects on equipment and product quality, implementation period, and required resources. A numerical rating system has been developed to assist in ranking choices (6). Finally, a recommendation is made. Preferred minimization options are then suggested to plant managers (3).

The final element in developing a minimization program is the actual program implementation. This involves developing, designing and installing process modifications and recovery and treatment systems. Employees must be informed of process changes, as well as the reasons for the changes. After implementation, a follow-up system can monitor progress and record waste stream quantity and disposition.

13.3.5 Current Status of Waste Minimization Programs

Due to increased expense and regulatory restrictions, many companies are now looking at ways to minimizing wastes (3). Some companies have qualitative waste minimization goals, such as lowering company disposal or new material costs. Other companies have set quantitative goals. For example, DuPont is currently reviewing a corporate goal of 5 percent waste reduction per year (7).

Used oil minimization has been on the upswing recently. As oil prices were low through the early and mid-1980s, many companies and individuals

frequently changed oil and bought new oil. This philosophy led to generation of large quantities of used oils. However, in the past few years, used oil regulations in California have become more restrictive. Liability and insurance costs have increased. It is also now necessary to pay transporters to haul used oil. Therefore, there are now increasingly attractive minimization incentives. As regulations and management costs escalate, minimization is expected to continue to increase in popularity in the forthcoming years.

13.4 Technological and Economic Trends

13.4.1 Technological Trends

Traditional recycling technologies were cost effective and able to produce easily salable fuel products. New technologies have emerged in recent years which can meet required standards as well eliminate hazardous waste by-products. The industry has been slow to embrace these new technologies due to lack of capital and lack of enforcement of the existing regulations.

Various technologies can reprocess used oil into marketable recycled oil. Technologies range from simple physical separation processes to complex, multi-stepped extraction processes. Reprocessing technologies exist to safely process used oil into fuel. They eliminate or reduce concentrations of harmful metals and other contaminants. Rerefining technologies can now recover over 95 percent of the used oil without generating hazardous waste by-products.

13.4.2 Economic Trends

The economics of the used oil industry currently encourage used oil recycling. Generators can reduce potential liability for pollution incidents and clean up by paying transporters to haul their used oil to an authorized recycler. Transporters can charge for transporting the generators' waste. This gives reprocessors and rerefiners a more consistent feed stream. Rerefiners have demonstrated that rerefined products are as good or better than virgin oil products.

Regulations have played a major role in the development of a stronger and safer recycling industry. Growing concern regarding the safe management of hazardous wastes led to regulatory guidelines for recyclers. The listing of used oil as a hazardous waste has forced the used oil industry to develop proper used oil management techniques. Management standards for used oil have encouraged some recyclers to upgrade facilities and equipment to protect public health and the environment. Recyclers who do not make the necessary changes expose themselves and their clients to potential enforcement action and liability.

13.5 Trends in Federal, State, and Local Regulations and Public Acceptance

As discussed in Chapter 5, used oil is not generally classified as a hazardous waste by EPA regulations. Such a ruling was proposed by EPA in November 1985. However, it was later decided not to list used oil as a hazardous waste because of potentially adverse impacts to used oil management. Another reason was the potential for increase in

uncontrolled disposal. Therefore, only used oil that has high halogen content and is to be used as fuel is classified as a hazardous waste under federal regulations.

Federal regulations governing used oil combustion have become more strict in recent years. Combustion for energy recovery is regulated by EPA under the waste-as-fuel rules published in the November, 1985 Federal Register. These rules prohibit burning hazardous waste and off-specification used oil in nonindustrial boilers. Due to their size and typical locations in residential areas, nonindustrial boilers can pose significant health threats if used to burn hazardous wastes.

In California, used oil has been classified as a hazardous waste since 1977. Used oil must be tested and shown to meet standards of purity before it is considered nonhazardous. Blending used oils with virgin products to meet specifications is prohibited. Generators, transporters, and recyclers must obtain either EPA numbers, EPA registration, or DHS authorization depending on pertinent state laws and regulations.

Local regulations are generally stricter than state regulations as a reflection of the public's "not in my back yard" philosophy. In particular, it is difficult to gain approval from localities to construct new land disposal sites. This in part explains the small number of such sites in California. Many local governments have also implemented hazardous waste generator registration programs in recent years. These programs can effectively quantify the type and amount of used oil generated.

13.6 Trends in Land Disposal Capacity

As mentioned in Chapter 5, land disposal capacity has diminished rapidly in recent years. Land disposal of oil waste and processing by-products must be in Class I hazardous waste land disposal sites. There are currently only two such sites in California. Small quantities of used oil are sent to land disposal sites. Only about 1.2 million gallons per year is managed in this manner. Diminishing land disposal capacity has caused a technological shift towards management methods that generate no waste by-products.

Land disposal capacity is limited because increasing environmental concerns have made it difficult to obtain permits for new hazardous waste disposal sites. Such sites have caused serious environmental problems in the past due to leaching and runoff of hazardous compounds. Local governments are often justifiably hesitant to allow hazardous waste disposal sites to be constructed in their localities. Consequently, today there is more emphasis on cleaning up contaminated existing sites than in developing new sites. The trend towards diminishing land disposal capacity is expected to continue in the future.

13.7 Existing and Emerging Technological Options

Of all reprocessed oils produced in California, 80 percent are utilized as fuel. Most of this reprocessed oil is burned as bunker fuel on ships. Kilns, furnaces, and external combustion boilers are also used. Reprocessing to produce fuel oil consists of separating excess water and solids, and removing contaminants so the oil meets California standards.

Commonly used unit operations include gravity separation, filtration, coalescing, extraction, and distillation.

Biological techniques are commonly used to destroy organic materials in oil wastes. Commonly used biological systems include trickling beds, activated sludge units, anaerobic digestion units, rotating contactors, and bioaugmentation units. Biological techniques are inexpensive. However, they are relatively slow and produce sludge that must be managed.

A number of rerefining methods are commercially available. Traditional acid-clay methods have recently diminished in popularity due to by-product disposal problems. Recently, methods such as the KTI process have been successful because they produce high quality lube oil and generate no wastes. Recycling and rerefining costs have increased in recent years. Capital investment and economics of scale favor fewer, larger facilities. This has favored large companies with solid economic backing.

A number of innovative technologies have recently shown signs of potential commercial success. Supercritical water oxidation uses properties of water above its critical point to oxidize organics, convert inorganic materials to salts, and liberate energy. The Zimpro wet oxidation process involves thermal oxidation of organics and inorganics in the aqueous phase under subcritical conditions. The B.E.S.T. process uses centrifugation with triethylamine to separate oils, water, and solids. Finally, centralized waste treatment facilities, such as the one operated by DuPont in New Jersey, accept contaminated oily wastewater from outside sources to utilize excess chemical treatment plant capacity.

13.8 Conclusion

Regulation of used oils has become increasingly strict in recent years, and this trend is expected to continue. Permitting, insurance, and handling costs have increased along with regulation. Traditional management techniques such as land disposal and incineration for waste destruction have declined in popularity because they can cause environmental problems and do not recycle the oil for any useful purpose. There has been a trend towards recycling techniques that generate little or no waste.

13.9 References

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2. "Minimizing Hazardous Wastes: What Are Your Options?," Haz. Waste Consultant, Sept./Oct. 1986, p. 1-1.
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4. Fromm, C.H., Bachrach, A., and Callahan, M.S., "Overview of Waste Minimization Issues, Approaches and Techniques," in Performance and Costs of Alternatives to Land Disposal of Hazardous Waste, APCA, Pittsburgh, 1987.
5. Parmele, C.S., Fox, R.D., and Standifer, R.L., "Waste Minimization Through Effective Chemical Engineering," in Performance and Costs of Alternatives to Land Disposal of Hazardous Waste, APCA, Pittsburgh, 1987.
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CHAPTER 14

OIL WASTE MANAGEMENT IN OTHER STATES AND COUNTRIES

Waste recovery systems in Europe and the U.S. are progressing in the same direction, after starting from very different initial positions. Fifteen years ago, Europeans stressed mass burning. Americans stressed processing waste for materials recovery and refuse derived fuel (RDF) (1). Ten years ago, American projects were reaching both completion and disillusionment. Americans then turned to mass burning. Europeans were disenchanted with the high cost of mass burning and concerned about air pollution problems. They turned toward materials recovery and RDF production. In the 1980s, the U.S. and Europe are no longer "searching for gold in garbage" (1). They have more level headed waste management goals. These goals will not be accomplished easily. It is against this backdrop that oil waste management regulations and practices have evolved.

14.1 Regulations

Other Countries

Hazardous waste technologies such as chemical treatment, biological treatment, incineration, and land disposal are almost identical around the globe. However, the regulatory structure within which these technologies are used varies greatly from country to country. Facilities in each nation are significantly different from one another (2).

Hazardous waste regulatory structures differ with the country's size and political structure. For example, Denmark is able to operate a centralized control system because of its relatively small and manageable size. West Germany encourages consensual programs in contrast to the adversarial approach inspired by U.S. politics.

The British avoid the use of the term "hazardous waste", preferring the term "controlled" waste (2). However, they require shipping papers for waste transportation. Management facilities must have licenses which specify environmental and operational conditions for waste handling and disposal. Local agencies have authority for licensing and enforcement of the license conditions. The national government provides technical expertise and guidance on proper management. Incineration and treatment facilities are available in the U.K. However, the preferred management option is co-disposal of liquid and solid "controlled" wastes with municipal refuse in specially designed landfills. The commercial waste industry in the U.K. recognizes that care must be taken in managing all wastes. However, disposal is generally more economical than treatment in the U.K. Current regulations provide limited incentives to implement alternatives to co-disposal. Therefore, co-disposal is expected to continue in the foreseeable future.

In France, transportation and rerefining, or "regeneration," are regulated by law (3). Used oil must be managed either by collection by an authorized agency or by proper chemical treatment. The government publishes a list of companies authorized to transport used oil. The minimum quantity for transportation is 200 liters, which is about one drum. The French

government encourages oil reuse and has a reuse program. Financing of this program comes from a petroleum company tax based on tonnage of virgin oil processed.

In West Germany, federal government regulations deal with used oil transportation and recycling (3). Used oils are fluids or semifluid materials which consist fully or partially of mineral oils. A fund was established in 1979 by the government to support programs which deal with used oil transportation to reduce environmental pollution. The minimum amount collected is 200 liters. Amounts less than 200 liters must be retained for future collection. Used oil collection is performed at no expense to the generator.

In Italy, a law has existed since 1940 to make used oil collection compulsory (3). This law establishes compulsory used oil collection by civil and military administrations, public bodies, industrial organizations, transport undertakings, workshops, garages, and service stations. All of these are required to release their used oil to the rerefining industry. Since 1962, a tax benefit has been granted to rerefiners based on rerefining oil volume. Because of this, Italy has become one of the most advanced countries in percentage of used oils rerefining.

In Japan, the Water Pollution Prevention Act controls disposal of oils from metalworking fluids (3).

Other States

A good source of information on used oil management and regulation throughout the U.S. is the report submitted to the EPA by Versar, Inc., Franklin Associates, and Jacobs Engineering Group in 1986 (4). Quoting from this report, "In the United States, eight to ten states currently regulate used oils either as a listed hazardous waste or as a "characteristic" hazardous waste under their respective State Laws. These states include California, Massachusetts, Missouri, New Jersey, New York, Oklahoma, South Carolina, and Vermont. Some of these states have had used oil regulations in effect for as long as 10-12 years (e.g. California and Massachusetts), while others have had regulations in effect for as little as 2-4 years (e.g. Vermont)".

The major conclusions from the above report are:

- Existing hazardous waste used oil regulations have not been actively enforced due to lack of funds, poor information dissemination, and the acceptance of used oil as a "low priority" waste.
- Some states categorize used oil facilities as "resource recovery" facilities to win public acceptance.
- All states encourage used oil recycling.
- Nearly all states exempt service station generators.

- In some states oil destined for recycling is exempt from regulation. In other states burning used oil meeting specifications is exempt from regulation.
- Several states exempt burners burning specification used oil.
- New Jersey gives tax credit for recycling of waste materials.
- Quantities of waste oil generated and recycled have remained relatively constant during the pre- and post-regulation periods.
- Changes in quantities of used oil recycled are more a function of recycled oil marketability and crude oil prices than regulation.
- In New Jersey and New York, service station owners are required to accept DIY used oil. Massachusetts, California, and Vermont have community sponsored or voluntary pickups for DIYs.
- In some states, used oil is no longer considered a waste upon being processed. In other states, it still qualifies as a waste unless the oil meets specification limits.

14.2 Technical Treatment Options

Technical options oil waste were discussed in Sections 4.3 and 8.2. These same options are available in all developed countries and all states of the U.S. The economics of a system are dictated by labor costs, power costs, chemicals costs, product quality required, utility costs, and local regulations. An economic study is required for each application, with strong emphasis on site-specific cost factors, before a process decision can be made.

14.3 Current Practices

With the present depressed virgin oil price structure, the incentives to rerefine used oil for the same uses as virgin oils, such as automotive lubes, are quite low. As a result, most recycled oils are burned as fuel. They are most commonly burned as bunker fuel, but also in space heaters, cement kilns, and asphalt plants in some states. Low product prices are pressuring processors to minimize treatment. Oils which meet specifications can be resold without treatment. Untreatable used oils may have to be burned in permitted incinerators or kilns.

Road oiling with used oil is being phased out in most states. It is still practiced in some remote areas.

Uncontrolled disposal is a problem for used motor oil because of the large amount of oil sold to DIYers and the reluctance of service stations to accept DIYer oil. They are mainly concerned with the cost of management and potential liability. This does not seem to be a concern in countries where used oil is picked up for free by the government.

Rerefining is very sensitive to crude oil prices. It is probably economically unfeasible when crude oil prices are low. In the U.S., the

rerefiner can charge the generator to take the generator's used oil. Even with this break, competition with collectors who resell used oil as bunker fuel without processing makes it difficult for the rerefiner to get an adequate supply of used oil. As mentioned above, Italy subsidizes its rerefining industry with a tax break.

14.4 Collection Programs

Collection programs vary from free government sponsored programs, as in West Germany, to fairly expensive programs, as in California. In all states and countries, collection programs are economically or convenience oriented. Many generators are becoming environmentally and liability minded, and prefer collection programs to irresponsible dumping.

14.5 Conclusions and Recommendations

All states and countries favor used oil recycling over disposal. In some cases governments have tried to eliminate negative economic factors. This can be done by providing non cost-effective services, such as free collection. Alternatively, tax subsidies can be given to preferred processing options, as Italy does for rerefiners. The U.S. tends to pass prohibitive laws forcing desired options rather than providing incentives to make these options economical. Incentive programs, such as New Jersey's recycling program, should be effective. However, these programs will be costly due to cheap crude oils prices. If crude oil prices increase sufficiently, economic incentives for rerefining will not be needed.

14.6 References

1. Abert, James C., "Waste Recovery in Europe," Waste Age, p. 65, October 1987.
2. Pirages, Suellen, "Co-Disposal is the Rule in Brittania," Waste Age, p. 81, October 1987.
3. Gabris, Tibor, "Emulsified Industrial Oils Recycling," DOE/BC/10183-1, April 1982.
4. Versar, Inc., Franklin Associates, and Jacobs Engineering Group, "Assessment of State Used Oil Management Practices and Regulations, Volume I," Draft Final Report, EPA Contract No. 68-01-7053, June 9, 1986.
5. "A Survey of Household Hazardous Waste and Related Collection Programs," EPA/530-SW-86-038, November, 1986.
6. "A Census of State and Territorial Subtitle D Non-Hazardous Waste Programs," EPA/530-SW-86-039, November, 1986.

CHAPTER 15
GLOSSARY

15.1 Glossary of Terms

Bioaugmentation:	Addition of specific bacterial mixtures to increasing the efficiency of biological waste treatment facilities.
Biodegradation:	Destruction of a material by microorganisms.
Biological options:	Techniques for the disposal or recycling of used oils through the use microorganisms.
Class I Disposal Facility:	Permitted facility for the disposal of hazardous wastes. Must be equipped with a clay liner, a synthetic liner, a blanket type leachate collection and removal system, an interim cover, both subsurface cutoff walls and grout curtains, probable maximum precipitation drainage control facilities and must be able to withstand the maximum credible earthquake (CAC Title 23, sec. 2521).
Contaminant:	Undesirable component of a used oil which results from the oil's use or mixing with other substances.
DIYer:	Do-it-yourselfer. A motorist who changes his own oil.
Emulsified Oil:	Suspension of very small oil droplets in water.
Generator:	Any person, by site, whose act or process produces hazardous waste or whose act first causes a hazardous waste to become subject to regulation (CAC Title 22, sec. 66078).
Halogenated Organics:	Hydrocarbons which contain fluorine, chlorine, bromine, or iodine.
Hauler:	See Transporter.

Hazardous Waste: A waste, or combination of wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may either:

- (a) Cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness.
- (b) Pose a substantial present or potential hazard to human health or environment when improperly treated, stored, or disposed of, or otherwise managed. (Section 25117 HSC)

Hydraulic Oil: Fluids used to transfer force. They are generally composed of various synthetic and petroleum compositions and are used in all types of machinery. The function of a hydraulic fluid is to maintain an incompressible state for as long as possible.

Land Disposal: Final disposal of waste materials either on or beneath the surface of land. Includes landfilling and landfarming.

Landfarming: Technique for enhancing the biodegradation of hazardous wastes by spreading them on the surface of a tract of land. Bacteria naturally present in the soil destroy organic compounds.

Landfill: A disposal facility or part of a facility where hazardous waste is placed in or on land and which is not a land treatment facility, a surface impoundment or an injection well (CAC Title 22 sec. 66123).

Lubricating Oil: Liquid petroleum or synthetic specially formulated products comprising a variety of grades that are used to decrease friction.

Metalworking Oils: Fluids that are used for both lubricating and cooling in various machinery processes (cutting, grinding, stamping and milling). Both water soluble and insoluble oils are used.

Off-spec Oils: Oils which do not meet the specifications set forth in 50 FR 49164. The specifications limit the concentrations of several key contaminants and set a minimum flash point.

Oil: Various synthetic and petroleum based compositions used as either hydraulic oils, transformer oils, metalworking oils, or lubricating oils.

Oily Wastewater: Wastewater contaminated with a small amount of oil (e.g. ballast or bilge water).

On-spec Oils: Oils which meet the specifications set forth in 50 FR 49164. The specifications limit the concentrations of several key contaminants and set a minimum flash point.

Pretreatment: Reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a publicly owned treatment works (40 CFR 403.3(q)).

Recyclable Hazardous Waste: Hazardous wastes which the Department of Health Services finds to be both economically and technically feasible to recycle. (Title 22, sec. 66796).

Recycle: A material is "recycled" if it is used, reused, or reclaimed (40 CFR 261.1(b)(7)).

Recycled Oil: Any oil, produced from used oil, which has been prepared for reuse and achieves minimum standards, in liquid form, as established by the Department of Health Services (Section 25250.1 (c), Chapter 6.5, Division 20, CA Health and Safety Code).

Recycler: Anyone other than a hauler or an onsite burner who participates in bringing used fluids to economic use.

Rerefine: To use refining processes on used oil to produce high quality base stock for lubricating and other petroleum products. Rerefining may include distillation, hydrotreating, and/or treatments employing acids, caustics, solvents, clay, and/or other chemicals.

Reuse: A material is "reused" if it is recycled.

Segregation: The separation of used oils from other types of wastes.

Sludge: Any solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial wastewater plant, water supply treatment plant or air pollution control facility exclusive of the treated effluent from a wastewater treatment plant (CAC Title 22 section 66193).

Source Reduction: Any activity or treatment that reduces or eliminates the generation of a hazardous waste within a process.

Thermal Options: Techniques for the disposal or recycling of used oils through the use of heat.

Transfer Station: A facility at which oils are stored but not generated, treated, handled or recycled.

Transformer Oil: Fluids used in electrical transformers for cooling and to provide a dielectric constant which is greater than that of air. Transformer oils consist of petroleum products, silicone fluids, and high molecular weight hydrocarbons.

Transporter: A person engaged in the offsite transportation of hazardous waste by air, highway, rail, or water (CAC Title 22 section 66214).

Treatment: Any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to render such waste nonhazardous, or less hazardous; safer to transport, store or dispose of; or amenable for recovery, amenable for storage or reduced in volume (CAC Title 22 section 66216).

TSD Facility: A facility permitted to treat, store or dispose of hazardous waste.

Used Oil: Oil that is no longer useful to its owner for its original purpose due to contamination through use or subsequent management.

Waste Minimization:

The reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored, or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either (1) the reduction of the total volume or quantity of hazardous waste, or (2) the reduction of toxicity of hazardous waste, or both, so long as such reduction is consistent with the goal of minimizing present and future threats to human health and the environment.

15.2 Glossary of Abbreviations

AEG	Attached/entrapped growth
APCD	Air pollution control device
ARB	Air Resources Board
Btu	British thermal unit
CAC	California Administrative Code
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CWMB	California Waste Management Board
DHS	California Department of Health Services
EPA	Environmental Protection Agency
HSWA	Hazardous and Solid Wastes Amendments
kg	Kilogram
l	Liter
lb	Pound
mg	Milligram
PCB	Polychlorinated biphenyl
PNA	Polynuclear aromatic
ppm	Parts per million
POTW	Publicly owned treatment works
PRC	Public Resources Code
RCRA	Resource Conservation and Recovery Act
RWQCB	California Regional Water Quality Control Board
SARA	Superfund Amendment and Reauthorization Act
SWRCB	California State Water Resources Control Board
TSD	Transfer, Storage and Disposal

APPENDIX A UNIT OPERATIONS OUTLINE

These unit operations are listed in groups according to their effect on used oil. Individual operations from these groups can be combined to synthesize a complete used oil treating process, e.g., recycling or rerefining. Acid treating has been omitted because it is no longer considered an option due to disposal difficulties with spent acid. Details about the individual unit operations are given above in Sections 4.3 and 8.3.3.

A.1 Solids Removal

- Gravity Settling
 - Ambient Temperature
 - Heated
- Filtration
- Magnetic Separation
- Centrifugation
- Hydroclones
- Flotation
 - Dissolved Air
 - Aeration

A.2 Emulsion Breaking/Water Removal

- Chemical Treatment
- Skimming
- Biological Treatment

A.3 Light Ends Removal

- Atmospheric Distillation
- Vacuum Distillation

A.4 Sludge, Metals, and Tar Removal

- Extraction/Deasphalting Techniques
 - Light Paraffins (C-2 to C-6)
 - Oxygenated Compounds (Alcohols and Ketones)
 - Supercritical Gases (CO₂ or Propane)

- Vacuum Distillation
- Clay Treating
- Sodium Treating
- Chemical Precipitation

A.5 Separation of Oil into Viscosity Grades

- Vacuum Distillation

A.6 Finishing of Oil

- Hydrotreating
- Clay Treating

APPENDIX B
ANNOTATED BIBLIOGRAPHY

This Appendix contains an annotated bibliography of literature related to oil waste management alternatives. The bibliography is divided into sections according to topic. All references cited in each chapter of the report are listed at the end of the chapter and repeated in this Appendix. In addition, a large number of sources not referred to in the text are included in this bibliography.

B.1 Characterization of Oil Waste

Beachey, J.E., and Bider, W.L., "Trends in Used Oil Composition and Management," Proceedings of the National Conference on Hazardous Wastes and Hazardous Materials, Hazardous Materials Control Research Institute, Silver Spring MD, 1986.

The U.S. EPA has attempted to minimize the health risks associated with improper used oil management by promulgating regulations under the authority of RCRA and the Used Oil Recycling Act. This report examines the changes occurring and expected to occur in used oil composition and management practices resulting from U.S. EPA regulations and changes in lead levels in gasoline.

Becker, D.A., ed., Measurements and Standards for Recycled Oil-IV, NBS SP 674, National Bureau of Standards, 1984.

This publication contains the proceedings of a conference held at the National Bureau of Standards, Gaithersburg, MD., on Sept. 14-16, 1982.

Beychok, M.R., Aqueous Waste from Petroleum and Petrochemical Plants, Wiley, New York, 1973.

This book describes refinery effluent streams and discusses treatment and management options. Topics covered include segregation systems, oil/water separators, oxidation processes and biological processes.

Bider, W.L., Composition and Management of Used Oil Generated in the United States, U.S. EPA Office of Solid Waste and Emergency Response Report No. EPA/530-SW-013, Washington D.C., Nov. 1985.

This report characterizes used oil management practices and comprehensively summarizes used oil composition. Concentration levels are summarized for 19 hazardous contaminants found in used oils. An assessment is made of the possible health and environmental implications of various used oil management practices.

Cotton, F.O., Whisman, M.L., Goetzinger, J.W., and Reynolds, J.W., "Analysis of 30 Used Motor Oils," Hydrocarbon Processing, Sep., 1977, p.131.

Results are presented of experimental tests performed on 30 used lubricating oils. Measurements were made of physical and chemical properties, and of concentrations of trace contaminants.

Jenks, J.M., Anselmo, V., Bradford, C., and Ehman, D., "Waste Oil Use in Texas: Lead, Sulfur, and Chlorine in Fuel Oils," 77th Annual Meeting of the Air Pollution Control Association, Paper 84-11.4, San Francisco, June 24, 1984.

This paper discusses results of experimental analyses performed to measure contaminants in waste oils, which include crankcase oil, lube oil, and hydraulic oil. Contaminant concentration data are compared to regulatory standards.

Luthy, R.G., Selleck, R.E., and Galloway, T.R., "Surface Properties of Petroleum Refinery Waste Oil Emulsions," Env. Sci. and Tech., 11: 13, 1211, (1977).

Surface properties of oil droplets in refinery wastewater are examined. Experimentally determined electrical parameters are compared to theoretical calculations. Measurements of the effects of water contaminants upon electrical properties are reported.

Munro, R.G., Hsu, S.M., and Weeks, S.J., Consistency Monitoring for Recycled Lubricating Oil Basestocks, U.S. Dept. of Energy Report No. DOE/BC/10749-3, Sep. 1985.

A study is done of the statistical relationships among an extensive number of measurable characteristics of base oils for the purpose of determining proper procedures for the consistency monitoring of recycled oils. Selection of representative variables is discussed, and an assessment is given of the significance of each variable.

B.2 Regulations

"Assessment of State Used Oil Management Practices and Regulations," Versar Inc., Draft Final Report to Angela Wilkes, USEPA Office of Solid Waste, Contract No. 68-01-7053, Washington D.C., June 1986.

An analysis is given of the effects of state and local legislation upon the management of used oil. Specific legislation examined includes the listing of used oil as a hazardous waste and allowable levels of contaminants.

Bergeson, L.L., "EPA to List Used Oil as a Hazardous Waste," Pollution Engineering, November, 1985.

Summarizes the EPA's proposal to list used oils as a hazardous waste.

"EPA Decides Not to Regulate Recycled Used Oil Under RCRA," Haz. Waste Report, Nov. 24, 1986, p. 3.

This article discusses the EPA's decision not to list recycled used oil as a hazardous waste. EPA believes that such a listing would cause millions of gallons of used oil to be disposed of in uncontrolled ways.

"EPA Issues Bulletin as RCRA Rules Disrupt Used Oil Recycling," Haz. Waste Report, July 7, 1986, p. 6.

This article discusses a bulletin released by the EPA clarifying the current federal regulations regarding used oil recycling.

"EPA Policy Office Discusses Credit Plan to Encourage Recycling of Used Oil," Haz. Waste News, June 29, 1987, p.243.

A review is given of the EPA's proposed plan to require oil refineries to certify that a certain amount of used oil has been recycled before they are allowed to produce new oil.

"EPA Proposes Schedule For Land Disposal Bans," Haz. Waste Consultant, July/August 1985, p. 2-16.

This article describes the EPA's required evaluation of contaminants to determine if they should be banned from land disposal. The schedule detailing when EPA will evaluate each substance is discussed.

Harris, C., "Superfund and Federal Controls Governing Used Oil," Haz. Waste Report, Nov. 26, 1986, p. 9.

This article discusses decisions made by the EPA regarding management and recycling of used oil, and potential listing of used oil as a hazardous waste.

Kuhl, E., and Gallagher, J., "Used Oil Regulation Proposed," Hazardous Materials Technical Center Bulletin, 5: 4, 8 (1986).

A summary is presented of burning of used oil in boilers, recycled used oil management standards, state regulatory programs, and Department of Defense used oil regulations.

"Land Prohibitions Finalized for California List of Hazardous Wastes," Hazardous Waste Consultant, Sept/Oct 1987, p. 2-1.

This article discusses the regulations which prohibit the disposal of wastes containing materials on the "California List" in land disposal facilities.

Leu, D.J., Chief Alternative Technology and Policy Development Section, Toxic Substances Control Division, California Department of Health Services, Personal Communication to Richard Valentinetti, March 8, 1985.

This letter is a response to a questionnaire regarding the proposed regulations in 40 CFR 266 which concern the burning of hazardous wastes. It describes California's policy on key issues related to used oil incineration.

Leu, D.J., Chief Alternative Technology and Policy Development Section, Toxic Substances Control Division, California Department of Health Services, Personal Communication to Diane Shell, February 7, 1986.

This letter summarizes the regulations used to classify used oils as a hazardous waste. It also outlines the implications of classifying used oils as a hazardous waste.

"Major Regulatory Programs Proposed for Used Oil," Hazardous Waste Consultant, Jan./Feb. 1986, p. 2-16.

Proposed EPA regulations are discussed that would create a regulatory framework to deal with used oil management and would list used oil as a hazardous waste. New regulations would be established for burning of used oil for energy recovery and recycling of used oil. Standards are described for managing and transporting recycled oil.

"Recycled Used Oil Will Not Be Listed as a Hazardous Waste," Hazardous Waste Consultant, Jan./Feb. 1987, p. 2-18.

This article describes the rationale behind the decision of the EPA not to regulate used oil as a hazardous waste. EPA believes that such regulation would promote illegal dumping of used oil and thus pose a net detriment to the environment.

"Regulation and Disposal of Used Motor Oil," Carnegie-Mellon University Department of Engineering and Public Policy, School of Urban and Public Affairs, and Department of Social Science joint Report prepared as a semester project, Pittsburgh, PA, December, 1987.

This report evaluates and critiques the EPA's past and current regulations regarding used oil. The potential threat of used oil and ways to reduce any risks it might pose to society are evaluated. The report focuses on the pathways and effects of motor oil.

"Regulations Finalized for Burning Hazardous Waste Fuels and Used Oil," Haz. Waste Consultant, Jan./Feb. 1986, p.2-11.

A description is given of new EPA regulations for burning used oils. A definition of used oil is given and used oil fuel specifications are listed.

"Regulatory Impact Analysis of Proposed Standards for Management of Used Oils," Temple, Baker & Sloane Inc., prepared for Economic Analysis Branch, USEPA Office of Solid Waste, Contract No. 68-01-6621, November 1986.

An analysis is given of the potential impacts of proposed legislation upon the management of used oil. Specific legislation examined includes the listing of used oil as a hazardous waste and decreasing allowable levels of contaminants.

"A Schizoid Policy on Used Oil," Lundberg Letter, Vol. XIII, No. 25, April 18, 1985.

This paper discusses the problem of uncontrolled disposal of used oil nationwide and how government and industry are reacting to the problem. An summary of the problem, government regulations, and industry response is given.

"Standards Proposed for Burning Hazardous Wastes in Boilers and Industrial Furnaces," The Haz. Waste Consultant, July/Aug., 1987, p. 2-11.

This article describes proposed regulations for hazardous waste incinerators, including emissions restrictions, and new trial burn standards.

Weiner, P.H., Attorney, Personal Communication to D.J. Leu, February 12, 1986.

The letter summarizes some of the sources which specify the statutory and regulatory authority of the state of California over waste oil activities.

West's Annotated California Health and Safety Code, West Publishing, St. Paul, MN.

This volume was written to consolidate and revise the laws relating to the preservation of the public health and safety.

B.3 Onsite Management

Chiconine, L.C., Gerdes, G.L., and Donahue, B.A., Reuse of Waste Oil at Army Installations, U.S. Army Construction Engineering Research Laboratory, Report No. CERL-TR-N-135, AD/A123 097, Champaign IL, September 1982.

The objectives of this report are to analyze the economics of waste oil reuse, and to examine the environmental aspects of used oil management. Three options were assessed: selling the oil to a rerefinery, burning it as boiler fuel, and recycling it in a closed loop agreement with a rerefiner.

Fromm, C.H., Bachrach, A., Callahan, M.S., "Overview of Waste Minimization Issues, Approaches and Techniques," Performance and Costs of Alternatives to Land Disposal of Hazardous Waste, New Orleans, Louisiana, Dec., 1986

This paper provides a discussion of the recently proposed EPA definition of waste minimization, along with discussions of issues such as dilution and dewatering, and how to measure waste minimization progress.

Fromm, C.H., Callahan, M.S., Freeman, H.M., and Drabkin, M., "Succeeding at Waste Minimization," Chem. Eng., 94:12, 91 (1987).

This article describes incentives, practices and methods for waste reduction and minimization. Plant waste audits, employee education, and improved housekeeping procedures are stressed as potential waste minimization measures.

Hollod, J.G., "Waste Reduction at DuPont," Government Institute Seminar on Waste Minimization, Los Angeles, Vol. 6, 1986.

This presentation describes the techniques DuPont is using to reduce waste production and presents the goals of their program.

Jacobs Engineering, "Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste from Parts Cleaning and From Electronic Capacitor Manufacturing Operations," Project Summary, H. Freeman Project Officer, EPA/600/S2-87/057, Nov. 1987.

This report presents the results of an on-site waste minimization audit performed at an electronic capacitor manufacturing facility for solvent wastes.

Knowlton, H.E., "Source Control Pays Off for Chevron," Oil and Gas Journal, Aug. 7, 1978, p. 87.

This article defines "source control" as it relates to in-plant activities undertaken by a waste generator and describes the benefits of a source control program at Chevron.

"Minimizing Hazardous Wastes: What Are Your Options," Haz. Waste Consultant, Sep./Oct. 1986, p. 1-1.

This article describes typical sources of hazardous waste, and discusses how improved operating practices and process modifications can be used to minimize hazardous waste production.

Parmelee, C.S., Fox, R.D., and Standifer, R.L., "Waste Minimization Through Effective Chemical Engineering," Performance and Costs of Alternatives to Land Disposal of Hazardous Wastes, New Orleans, Louisiana, Dec. 1986, p. 115.

Reviews the common elements in some successful waste minimization programs.

Waste Petroleum Segregation Study, Recon Systems Inc. report for Naval Facilities Engineering Command, Contract No. N00025-81-C-005, Alexandria VA, August 1982.

The objective of this study is to provide guidance on recycling Navy used petroleum products in the most cost effective and environmentally sound manner possible. The underlying philosophy of this study is to achieve recyclability of used oil products and solvents for their original use or similar applications as close to the source of generation as possible.

B.4 General Management

Bartha, R. and Bossert, I., "The Treatment and Disposal of Petroleum Wastes," in Petroleum Microbiology, MacMillan, New York, 1984.

This article describes regulations and techniques for managing petroleum wastes. Among treatment methods discussed are rerefining, land disposal, biological treatment, and incineration.

"Chemical Treatment, Incineration, and Landfilling Evaluated for Hazardous Waste Management," Hazardous Waste Consultant, July/August, 1985, p 1-16.

Describes the three main options for treating hazardous wastes and compares the advantages and disadvantages of each. Detailed economic discussion is included.

Cope, C.B., Fuller, W.H., and Willetts, S.L., The Scientific Management of Hazardous Wastes, Cambridge Univ. Press, Cambridge, 1983.

This book discusses the technical, regulatory, and economic aspects of hazardous waste management. Individual chapters examine landfilling, incineration, and chemical treatment of hazardous wastes.

DeRenzo, D.J., Unit Operations for Treatment of Hazardous Industrial Chemical Wastes, Noyes Data Co., Park Ridge NJ, 1978.

This book describes unit operations such as centrifugation, filtration, distillation, and evaporation, and describes when and how each operation is used in treating hazardous wastes. Potential applications, energy requirements, and economics are also discussed.

Gottlieb, M., Analysis of Potential Used Oil Recovery from Individuals, Dept. of Energy Report No. DOE/BC/10053-21. Bartlesville OK, July 1981.

A telephone survey was conducted of individuals who change their own motor oil. This study examines the amount of oil used, oil change practices, oil disposal methods, and perceptions and attitudes toward used motor oil disposal and recycling. A probability sample of 4805 households in the U.S. was used for this study.

Hess, L.Y., Reprocessing and Disposal of Waste Petroleum Oils, Noyes Data Co., Park Ridge NJ, 1979.

This book describes new developments in the field of waste oil recovery and disposal. Information in the book is based on detailed information from U.S. Government laboratories and from government sponsored studies done by university teams and engineering companies. Used oil management techniques and economic data are presented.

Howard, D., Waste Oil: North Carolina's Recovered Resource, The Council of State Governments, Raleigh NC, 1980.

This report summarizes waste lubricating oil recycling and rerefining activities in North Carolina. The state rerefines between 300,000 and 500,000 gallons of used motor oil annually and sells the high-quality oil produced to state agencies for use in their vehicles. Recycled oil production and cost data are provided.

Kohl, J., and Currier, J., Managing Used Oils, North Carolina State School of Engineering Report prepared for the North Carolina Board of Science and Technology, Raleigh NC, March, 1987.

This manual provides current information on used oil regulations and management options, including source reduction, disposal, and treatment options. Management case studies are presented. Analytical used oil testing techniques are described.

Mackie, J.A., and Nielsen, K., "Hazardous Waste Management: The Alternatives," Chem. Eng., Aug. 6, 1984, p. 51.

A discussion is presented of the management options and regulations facing engineers who deal with hazardous wastes. Management options fall into the categories of destruction, reduction, and isolation.

Martin, W.F., Lippitt, J.M., and Prothero, T.G., Hazardous Waste Handbook for Health and Safety, Butterworths, Boston, 1987.

This handbook describes causes, effects, and mitigation measures for hazardous waste management. Hazardous waste control methods, decontamination, and site characterization are discussed.

"Notes from Seminar on Hazardous Wastes in Used Oils and Fuels," Auburn University, May 1987.

These notes describe the current state of technology for waste oil processing. Advantages and disadvantages of various rerefining processes are discussed, including the Recyclon Process, KTI process, IFP propane process, Matthys process, PROP process, and BERC process.

"Preliminary Investigational Requirements— Petrochemical and Refinery Waste Treatment Facilities," EPA Water Control Research Series, No. 12020 EID 03/71, 1971.

This report details a study performed upon oil refineries to determine the most commonly used and effective methods of handling petroleum wastes.

Pritchard, S.Z., Oil Pollution Control, Croom Helm LTD, Wolfboro NH, 1987.

This book summarizes the history of oil pollution. Regulatory, environmental, and economic trends are traced through the twentieth century.

Rousseau, R.W., Editor, Handbook of Separation Process Technology, 1987.

This book gives a discussion of liquid-liquid separation devices, giving choices based on particle size, dispersed phase concentration, and available space for equipment.

Sittig, M., Organic and Polymer Waste Reclaiming Encyclopedia, Noyes Data Co., Park Ridge, NJ, 1981.

This book describes 335 processes for reclaiming organic and polymer wastes. Sources of waste feed material are listed, as well as the products that can be reclaimed from the waste feed.

Sittig, M., Pollution Control in The Organic Chemistry Industry, Noyes Data Co., Park Ridge, NJ, 1974.

Methods for treating chemical waste products are described, including oil/water separations and conversion of oil to synthetic natural gas.

Smookler, A.L., and Harden, J.W., Annapolis 1975 Conference on Prevention and Control of Oil Pollution, Naval Ship Research and Development Center, CONF-750386, March 25, 1975.

The Navy's shipyard oily waste problem is defined. The nature, sources, and generation rates of oily waste produced by naval ships while in port or at sea under various modes of operation are presented. Principal bilge fluid sources are identified, and methods of reducing the volume of bilge fluids generated are explained.

Used Oil Collection System: Guides for Developing a Collection Network, KTI Used Oil Division, Monrovia CA, 1987.

A description is given of the most important elements of a successful used oil collection system. Subjects include choosing used oil sources, collection routes and proper collection equipment.

Wark, K, and Warner, C.F., Air Pollution: Its Origin and Control, Harper and Row, New York, 1981.

This textbook describes the formation and dispersion of air pollutants. It also presents the fundamentals behind air pollution control techniques.

Waste Oil Management Conference Proceedings, Amoco Research Center, Naperville IL, April 3, 1980.

Proceedings from a conference dealing with the conservation, reclamation, recycling, and reuse of lubricating oils are presented. In-plant oil accounting, recycled oil standards, rerefining processes, and economic analysis are among the topics covered.

Waste Oil Recovery and Reuse, Proceedings from the International Conference on Waste Oil Recovery and Reuse. Sponsored by the Association of Petroleum Rerefiners, Washington D.C., Feb. 12, 1974.

This volume discusses the need for oil reuse, and details the available waste oil management practices. Subjects discussed include government waste oil programs, waste oil characteristics, products derived from used oils, and use of waste oil as fuel.

Wilde, T.S., Used Oil: Waste Processes, University of Utah Bachelor of Science Thesis, Salt Lake City, 1987.

This thesis catalogues various methods of waste oil treatment, determines which treatments are applicable for used and aqueous used oils, examines which of these treatments are legal and practical in California, and describes three emerging treatment technologies: supercritical water oxidation, biodegradation, and centrifugation with triethylamine.

Wilson, D.C., Waste Management: Planning, Evaluation, Technologies. Clarendon Press, Oxford, 1981.

This book discusses methods for managing waste oils and other hazardous wastes. Methods discussed include waste reduction, resource recovery, incineration, chemical treatment, biological treatment, and land disposal.

B.5 Recycling

Barton, A.F. Resource Recovery and Recycling, Wiley, New York, 1979.

A discussion is presented of factors influencing recycling feasibility, physical and chemical methods of separation, industrial recycling and microbiological recycling.

Becker, D., "Oil Recycling," in Recycling, Fuel and Resource Recovery: Economic and Environmental Factors, Wiley, New York, 1984.

This article describes characteristics of used oils, used oil management techniques, and rerefined oil specifications. Used oil analyses as taken from literature sources are reported.

Brinkman, D.W., "Waste Hydrocarbon Recycling," Chem. Eng. Progr., March, 1986, p. 67.

This article describes the effects of the world oil market on the recycling of petroleum products. Processes are described for recycling used lubricating oils.

Directory of Industrial Waste Recyclers, California Dept. of Health Services, Toxic Substances Control Division, Sacramento CA, 1987.

This directory is a listing of commercial recyclers in California. For each waste type, names and addresses of recyclers are listed, along with the specific types of waste they will accept.

Holmes, J.R., Refuse Recycling and Recovery, Wiley, New York, 1981.

This book describes waste recovery, reuse, combustion, and disposal. Specific industrial systems and treatment methods are reviewed.

Moskat, G.W., Stone, D., and Tipon, K.E., Used Oil Recycling in California, California Waste Management Board Publication, Sacramento. December, 1983.

This report summarizes activities related to used oil management and recycling in the state of California in 1983. Data is given on used oil generation, collection, recycling, and disposal in California. Enforcement activities and future used oil management programs are described. Lists of registered used oil handlers are given.

Moskat, G.W., Oil Recycling 1982, California Waste Management Board Annual Report, Sacramento. July, 1982.

This report summarizes activities related to used oil management and recycling in the state of California in 1982. Activities and goals of the California Waste Management Board's oil recycling public education program are described. Data is given on used oil generation, collection, recycling, and disposal in California.

Nolan, J.J., Used Oil: Reuse and Recycling Strategies, RCRA Update Conference, Government Institutes Inc., Washington D.C., February 17, 1987.

This paper summarizes current and proposed used oil regulations and describes recycling options available to used oil handlers. Rerefining, incineration, and road oiling are discussed.

Noll, K.E., Haas, C.N., Schmidt, C., and Kodukula, P., Recovery, Recycle and Reuse of Industrial Wastes. Lewis Publishers, Chelsea MI, 1985.

This book describes methods that can be used in the the elimination of industrial wastes through the application of recycle, recovery, and reuse technologies. The book is a culmination of an extensive review of literature in this area.

Program Guide to Used Oil Recycling, Prepared by Centec Corporation and Energetics Incorporated, Department of Energy Report No. DOE/CS/40402-1, January 1982.

The purpose of this booklet is to provide information necessary to organize a used oil recycling program, establish collection points, and enlist the cooperation of concerned individuals and groups.

Recycle Used Motor Oil: A Model Program. Second Edition, American Petroleum Institute Publication 1591, Washington, D.C., 1979.

This manual outlines a detailed program for the collection and recycling of used motor oil generated by the motorist who drains his own engine oil. Community education, collection methods, and incentive programs are described.

Recycling, Fuel and Resource Recovery: Economic and Environmental Factors, Ed. by Grayson, M., Wiley, New York, 1984.

A description is given of energy management, fuels from waste, recycling, and wastewater treatment. Used oil characteristics and recycling options are discussed.

Recycling of Used Oils, Proceedings of Second European Congress on the Recycling of Used Oils, D. Reidel Publishing Co., Dordrecht, Holland, 1981.

This conference was held to characterize current international practices and policies concerning used oil management. Oil recycling practices are summarized for the U.S., France, Ireland, Italy, Belgium, Great Britain, and West Germany. Innovative used oil treatment techniques are described.

Salvesen, R.H., Used Oil and Solvent Recycling Guide, Prepared for Dept. of the Navy, Naval Energy and Environmental Support Activity Contract N62474-84-C-3377, Port Hueneme CA, June, 1985.

The purpose of this guide is to help implement the Chief of Naval Operations directive that bans disposal of used solvents and requires naval facilities to initiate used solvent elimination programs. Chapter 1 of this guide deals with solvent elimination. Chapter 2 provides guidance and information for recycling used oil.

Sittig, M., Resource, Recovery and Recycling Handbook of Industrial Wastes, Noyes Data Co., Park Ridge, NJ, 1975.

This handbook demonstrates how industrial wastes can be turned into resources, concentrating on the process technology available for resource recovery and recycling. Included is a discussion of the recovery and conversion of oils to usable products.

Stone, D.P., Moskat, G.W., and Tipon, K.E., Used Oil Recycling in California 1984, California Waste Management Board, Sacramento. July, 1985.

This report summarizes activities related to used oil management and recycling in the state of California in 1984. Data is given on used oil generation, collection, recycling, and disposal in California. Activities conducted by the California Waste Management Board in the area of raising public awareness about oil recycling are described. Registered used oil handlers are listed for each county in California.

Used Oil Recycling in California, California Waste Management Board Publication, Sacramento, July 1986.

This report summarizes activities related to used oil management and recycling in the state of California in 1985. Data is given on used oil generation, collection, recycling, and disposal in California. Activities conducted by the California Waste Management Board in the area of raising public awareness about oil recycling are described. Registered used oil handlers are listed.

Ways the Department of Defense Can Improve Oil Recycling. Report to Congress, General Accounting Office, Logistics and Communications Division, Report No. LCD-77-307, Washington D.C., Sept. 28, 1977.

This report discusses federal agencies' disposal of used lubricating oil, the leadership needed to manage this resource, and actions the Department of Defense could take to improve oil recycling.

B.6 Rerefining

Berry, R.I., "Oil Rerefining Route is Set for Two Plants," Chemical Engineering, Oct. 5, 1981.

A process is described in which used oil is treated using a series of vacuum distillation steps. The technology recovers 97 percent of dehydrated used oil as marketable products.

Berry, R.I., "Rerefining Waste Oil," Chem. Eng. 86: 9, (104), 1979.

Recently developed methods may make rerefining waste oils more attractive. Three processes are discussed and compared: Phillips Petroleum Company's PROP, Kinetics Technology International (KTI), and Leybold-Heraeus GmbH's Recyclon.

Bigda, R.J. and Cowan, T.M., Used Oil Rerefining, Collection- Technology- Economics. 1980.

This comprehensive manual is dedicated to used lubricating oil collection, processing, and marketing.

Booth, G.T., Odojewski, S.S., and Brinkman, D.W., Used Lubricating Oil Rerefining Demonstration Plant Data Acquisition, Topical Report I: Environmental Considerations, DOE/BC/10562-5, Buffalo, NY, Jan., 1983.

This report describes the multitude of environmental laws, regulations and other considerations which need to be addressed to design and build a new rerefining facility. Work performed in accessing the theoretical and actual air emissions emanating from the facility as well as a description of the wastewater treatment system is discussed.

Canada, J.R., North Carolina Used Motor Oil Rerefining Program: Topical Report 3, Economics, Logistics, and Operating Results, DOE/CS/40338-3, July, 1983.

This report describes the financial results, cost-variance analyses, production impediments associated with the construction of a state operated rerefining system. The report also projects future operating volumes necessary for the facility to cover costs.

Cotton, F.O., Brinkman, D.W., Reynolds, J.W., Goetzinger, J.W., and Whisman, M.L., Pilot-Scale Used Oil Rerefining Using a Solvent Treatment Distillation Process, BETC/RI-79/14, Bartlesville OK, Jan., 1980.

Used automotive lubricating oil was collected and processed using the patented technology developed by the Bartlesville Energy Technology Center. The resulting lube oil basestock was tested by both physical and chemical analytical techniques, and in engine sequence tests. Analyses of the oil are presented at the end of each stage of processing to demonstrate the effects of that stage.

Deutsch, D.J., "Bright Prospects Loom for Used Oil Rerefiners," Chem. Eng., July 30, 1979, p.28.

This article describes how emerging technologies and government programs are combining to revitalize the used oil rerefining industry.

Dumortier, J., "Matthys/Garap Techniques," Third International Conference on Waste Oil Recovery and Reuse, Association of Petroleum Rerefiners, Houston, Oct. 16, 1978.

The individual stages of the Matthys/Garap waste oil rerefining process are described. The main innovations of the process and the manner in which they are achieved are discussed.

Engineering Design of a Solvent Treatment/Distillation Used Lubricating Oil Rerefinery, Stubbs Overbeck and Assoc. Inc. Report for Dept. of Energy, Report No. DOE/BC/10008-9. June, 1980.

Drawings and specifications are presented for a 10 million gallon per year used lubricating oil rerefinery based on the solvent treatment/distillation process developed by the Department of Energy's Bartlesville Energy Technology Center. Capital cost estimates are provided. Flowsheets are also provided for facilities to treat 2, 5, and 20 million gallons per year.

Falconer, M., et al, "Rerefining Used Lubricating Oils," Pollution Engineering, June, 1986, p. 44.

This article describes a process using distillation and hydrotreating to rerefine used lube oils to virgin oil standards.

Krupp, F., Regenerating Used Oils, Belgian Patent 880,074 (Cl.C10M/), March 17, 1980; German Application 2,850,540, Nov. 22, 1978.

Used lubricating oils are dried and regenerated by stripping with an inert gas. The recovered material is separated into fractions in a second step. Suitable inert gases are CO₂, C₃H₄, or mixtures of ethane/ethylene or propane/propylene.

Kubarewicz, J., Shea, T., Mikucki, W., Feasibility of Department of Defense Used Oil Lubricating Oil Rerefining, Report CERL-TR-N-171, Dec. 1983.

This report describes a study which examined the feasibility of capturing and rerefining all of the Department of Defense's used lubricating oil. The quantities of virgin oil used, the potential for capturing the used oil and the level of technical sophistication available in the rerefining industry are examined.

Linnard, R.E., and Henton, L.M., "Rerefine Waste Oil with PROP," Hydrocarbon Proc., Sep., 1979, p. 148.

This article describes the Phillips rerefining process (PROP), which combines chemical demetalization with hydrotreating to produce base oils from waste lubes. An analysis of the status of the rerefining industry is also given.

Linnard, R.E., and Henton, L.M., "PROP (Phillips Petroleum Company Rerefining Oil Process) —An Innovation in Used Oil Rerefining," National Petroleum Refiners Association Annual Meeting, Paper no. AM-79-21, San Antonio, March 25, 1979.

This discussion of the PROP process covers the status of the rerefining industry, technical details of the PROP process, operating experiences in a PROP plant, and economic viability of the PROP process.

Morris, K.L., "United States Rerefining - 1980," in Recycling of Used Oils, D. Reidel Publishing Co., Dordrecht, Holland, 1980.

This paper summarizes the state-of-the-art of U.S. used oil recycling. Recent changes in the U.S. rerefining industry are summarized. Currently available rerefining technologies are described.

"New Lube Oil Recycling Process Developed," Oilweek, 31: 5, 54, Calgary, Alberta, 1980.

British Railways has developed and patented a blend of chemicals that coagulates most of the contaminants in used lubricating oil, removing insoluble matter, and leaving unused portions of the additives. It is claimed to be cheaper than the rerefining processes now in use.

"New Technology Recycles Used Oil," Haztech News, 1: 8, 145 (1986).

A description is given of the Evergreen Oil refinery, which turns used oil into lubricating oil, fuel oil, and asphalt flux while producing no wastes.

Pao, J.H., Wilson, D.B., and Brinkman, D.W., Hydrotreating for Rerefined Lubricating Oil, Bartlesville Energy Technology Center, Contract No. DE-AS19-8013C10332, DOE/BC/10332, 1982.

This report describes development work performed by the Bartlesville Energy Technology Center concerning hydrotreating used oils. Eight commercially available hydrotreating catalysts were evaluated. Product quality was evaluated in terms of color, viscosity, and sulfur content.

Ratcliffe, C.J., "The Quality of Products Regenerated in Accordance with Modern Techniques," in Recycling of Used Oils, D. Reidel Publishing Co., Dordrecht, Holland, 1980.

Regenerated base oils from a variety of European sources are analyzed to assess their suitability for use as lubricating oil. The samples are representative of the regenerated oils that are commercially available. Analytical results are tabulated and these results are discussed in the context of selection and suitability of the regenerated base oils for formulation of lubricating oils.

Review of All Lubricants Used in the U.S. and Their Rerefining Potential, Richard J. Bigda and Associates Report for Dept. of Energy, Report No. DOE/BC/3022701, Bartlesville OK, June 1980.

The purpose of this handbook on lubricating oils and their use is to assist those persons in the waste oil collecting and recycling business. The first two sections deal with processing steps and ingredients of a lubricating oil. The remaining sections deal with specific types of lubricating products manufactured in the United States. Information is also provided on used oil sources, availability, and contamination.

Short, H., Hunter, D., and Parkinson, G., "Three Rerefining Methods for Waste Lube Oils," Chem. Eng., July 20, 1987, p. 21.

This article describes technologies used by Kinetics Technology International, Snamprogetti, and IFP Co. to rerefine used oils. Technology and economics of each method are discussed.

Thompson, C.J., and Brinkman, D.W., "Energy Saving by Rerefining Used Oils," in Recycling of Used Oils, D. Reidel Publishing Co., Dordrecht, Holland, 1980.

This paper comparatively evaluates burning of used oil versus rerefining. Areas that are evaluated include the energy advantage to be realized in terms of resource conservation as well as an estimation of the economics and profit motives currently available in the disposition of used lube oil. The data show rerefining superior to burning in terms of resource conservation.

"Waste Oil Rerefining," Hydrocarbon Processing, Sep. 1980, p.143.

This article describes use of the Snamprogetti process for rerefining spent oils from internal combustion engines.

Weinstein, K.D., Myers, T.D., and Craft, S.R., Enhanced Utilization of Used Lubricating Oil Recycling Process By-Products, Dept. of Energy Report No. DOE/BC/10059-19, Bartlesville OK, March 1982.

A study is conducted of possible utilization options for the process by-products generated in the rerefining of used lubrication oils. Viable options are found for all by-product streams. Economic analyses are performed where data exists.

Whisman, M.L., Reynolds, J.W., Goetzinger, J.W., Cotton, F.O., and Brinkman, D.W., "Rerefining Makes Quality Oils," Hyd. Proc., October 1978, p. 141.

A description is given of the BERC process, which removes contaminants from used automotive lubricating oil, and returns the oil to a quality equivalent to oils produced from virgin stocks. The process incorporates a solvent precipitation step to reduce coking and fouling in the subsequent fractional distillation. By-Products are usable as asphalt or as fuel.

B.7 Thermal Treatment

Bendersky, D., Keyes, D., Luttrell, M., Simister, B., Simister, M., Viseck, D., Savage, G., and Shiflett, G., Resource Recovery Processing Equipment, Noyes Data Co., Park Ridge NJ, 1982.

This book provides information concerning the design, selection, and operation of resource recovery processing equipment for existing and future waste-to-energy systems.

Boyd, J.D., "Regulatory Aspects of Incineration," Proceedings of First National Symposium on Incineration of Industrial Wastes, Toxcon Engineering Co. and Randolph, Breyer and Associates, San Diego, March 13, 1987.

This paper discusses regulatory and siting issues as they relate to air pollution from waste incineration facilities in California. Regulatory authority and specific statutes and regulations are described.

Castaldini, C., Willard, H.K., Wolbach, C.D., Waterland, L.R., Hall, F.D., Kemner, W.F., Annamraju, G., Krishnan, R., Taft-Frank, M.A., and Albrinck, D.N., Disposal of Hazardous Wastes in Industrial Boilers and Furnaces, Noyes Data Co., Park Ridge NJ, 1986.

This book documents a feasibility study done to determine whether industrial boilers could potentially be used for safely destroying hazardous wastes. It also evaluates the potential use of high-temperature processes for the incineration of hazardous wastes. Combustion of contaminated excess spent oils is discussed.

Cook, D.A., "Lead Emissions from Waste Oil Combustion in Steel Production: A New Concern," 77th Annual Meeting of the Air Pollution Control Association, Paper 84-11.5, San Francisco, June 24, 1984.

This paper characterizes emissions of lead from various steel manufacturing waste oil combustion devices, including blast furnaces, open hearths, sinter plants and coke ovens. Difficulty in determining typical waste oil lead levels is discussed. Regulatory background information is presented.

Cottone, L.E., and Falgout, D.A., and Licis, I., "Sampling and Analysis of Hazardous Waste and Waste Oil Burned in Three Asphalt Plants", In Incinerating Hazardous Wastes, Ed. by H.M. Freeman, Technomic Publishing Co., Lancaster PA, 1988.

Results are presented of experiments in which the destruction and removal efficiency of organic compounds were measured in asphalt plants burning 100 percent waste oil. Emissions of metals and other contaminants were also measured.

Dillon, A.P., Bonner, T., Desai, B., Fullenkamp, J., Hughes, T., Kennedy, E., McCormick, R., Peters, J., and Zanders, D., Hazardous Waste Incineration Engineering, Noyes Data Co., Park Ridge NJ, 1981.

The engineering guidelines in this book are a compendium of material available in the literature on the current state-of-the-art technology for hazardous waste incineration. They are intended to be used as a source of information for operational decisions and as a reference in the preparation of permit applications for hazardous waste incineration facilities.

Feasibility of Cofiring Oily Sludges in Boilers at Specific Navy Facilities, Acurex Co. Report for Naval Civil Engineering Laboratory, Report No. CR84.036, Port Hueneme, CA. Sep. 1984.

In this report, seven Naval installations are investigated to determine the feasibility of cofiring Navy generated oily sludges in existing boilers. Feed characteristics, life cycle costs, and permit requirements are used in the analysis.

Fennelly, P. F., McCabe, M., and Hall, J., "Environmental Characterization of the Combustion of Waste Oil in Small Boilers," In Incinerating Hazardous Wastes, Ed. by H.M. Freeman, Technomic Publishing Co., Lancaster PA, 1988.

This report discusses results of air emissions tests done on seven boilers firing waste oil. Data are given to document the extent to which chemical contaminants in waste oil are destroyed during the combustion process.

Fennelly, P. F., McCabe, M., and Hall, J., "Environmental Characterization of Waste Oil Combustion in Small Boilers," Hazardous Waste, Vol. 1, No. 2, 1984.

This report discusses results of air emissions tests done on seven boilers firing waste oil. Data are given to document the extent to which chemical contaminants in waste oil are destroyed during the combustion process.

Fu, T.T., and Chapler, R.S., Waste-Oil Boiler Firing Demonstration at NAS Miramar, San Diego, California, U.S. Dept. of Navy Chief of Naval Materials Report No. TN1618, Port Hueneme, CA, January, 1982.

This report describes tests done by the Navy in which waste oils were mixed with no. 6 fuel oil in existing boilers. Technical details and test results are reported. It was found that the waste oils could be fired with no modifications to the existing boilers.

Gin, W., Williams, G., and Eriksson, R., "Permitting of Hazardous Waste Incinerators," Presented at Incineration of Industrial Wastes, Toxcon Engineering Co. and Randolph, Breyer and Associates, San Diego, March 13, 1987.

This paper discusses permitting of hazardous waste incinerators from a regulatory perspective. Subjects identified include information required in RCRA permit applications and the information review process.

Hall, R.E., Barbour, R.L., and Cooke, W.M., Chemical Analysis of Waste Crankcase Oil Combustion Samples, EPA-600/S7-83-026, June 1983.

Two waste oil heaters were tested while firing filtered, but otherwise untreated, waste crankcase oils. Emissions from the two waste-oil-fired space heaters were sampled and analyzed. Pot residues were also analyzed. It was found that relatively high levels of metals and organics were released to the atmosphere.

Hall, R.E., Cooke, W.M., and Barbour, R.L., "Comparison of Air Pollutant Emissions from Vaporizing and Air Atomizing Waste Oil Heaters," JAPCA, 33: 7, 683 (1983).

Information presented in this paper is directed towards individuals concerned with emissions from combustion of waste crankcase oil for space heating. Studies were performed to characterize gaseous and particulate emissions and vaporizing pot solid residues resulting from the combustion of waste crankcase oil. Both vaporizing and air atomizing oil burners were tested.

Harris, J.C., Larsen, D.J., Rechsteiner, C.E., and Thrun, K.E., Combustion of Hazardous Wastes Sampling and Analysis Methods, Noyes Data Co., Park Ridge NJ, 1985.

Sampling and analysis methods for the measurement of hazardous constituents found in the influent and effluent streams at hazardous waste incineration facilities are described in this book. Included in the book are concise summaries stating recommended methods, types of samples and specific analytes to which a method applies, a brief description of the method and instrumentation and operating conditions.

LePera, M.E., and DeBono, G., "Investigation of Waste Oil Disposal by Direct Incineration," JAPCA, 27: 2, 144 (1977).

A program was initiated at Aberdeen Proving Ground, Maryland, to dispose of generated waste oil by firing it as a supplement to No. 6 fuel oil. The fuel oil was then changed to the No. 2 grade. Stack emissions data are presented for cofiring of waste oil with both No. 6 and No. 2 fuel oils.

McCormick, R.J., DeRosier, R.J., Lim, K., Larkin, R., and Lips, H., Costs for Hazardous Waste Incineration, Noyes Data Co., Park Ridge NJ, 1985.

Relationships between capital, and operation and maintenance (O&M) costs for hazardous waste incineration and the various waste-specific, design-specific, and operational factors that affect these costs are discussed in this book.

Menczel, J., Ehmann, J., and Tornick, B., "The Regulation of Hazardous and Toxic Substances in Waste Oils Used as Fuels," 77th Annual Meeting of the Air Pollution Control Association, Paper 84-11.1, San Francisco, June 24, 1984.

This study involves sampling of waste oil tanks and then analyzing each sample qualitatively and quantitatively for selected components. The program includes a baseline study of virgin oils and a comparative study of samples obtained from waste oil dealers and users. Analytical methods and regulatory standards are also described.

Munson, J., and Vincent, R., Assessment of Used Solvent and Used Oil as Fuel in California, California Air Resources Board, Sacramento, January, 1985.

This report identifies quantities of waste-derived fuels used in California, the constituents of concern and their concentrations in the fuels, typical users of waste-derived fuels, and the type of combustion devices using these fuels. Both solvent- and oil-derived fuels are considered. A discussion is also provided on the need for further controls on combustion facilities.

Star, A.M., "Cost Estimating for Hazardous Waste Incineration," Pollution Engineering, April 1986, p.21.

Estimations are made of capital and operating and maintenance costs for hazardous waste incinerators. Cost varies according to waste compositional characteristics, and the capacity, design, and operation of the system.

Tanner, R.K., "Incineration of Hazardous Waste," Prog. Energy Combust. Sci., 1979, Vol. 5, 1979, p. 245.

This article summarizes incinerator design and operating information, and describes hazardous waste incineration regulations. Typical waste properties are tabulated. Potential problems associated with hazardous waste waste storage, handling and incineration are described.

Tarrer, A.R., and Fellows, H., Hazardous Wastes in Used Oils and Fuels, Seminar presented by Auburn Univ., August 1987.

This report is the lecture note volume for a seminar developed by Auburn University and held at Raleigh, North Carolina on August 11, 1987, and at Charlotte, North Carolina on August 12, 1987. The seminar covered federal regulations and their impact on waste oil, as well as waste oil management, utilization and disposal.

Used Oil Burned as a Fuel, Vol. 1 and 2, Recon Systems Inc., and ETA Engineering Inc., EPA Publication No. SW-892, 1980.

This report is an assessment of the environmental impact of used oil combustion. The report contains data available in the literature, analysis of combustion tests done on steam boilers, and air dispersion modelling.

Waite, D.A., Jarvis, K.C., Davis, J.G., Lavin, P., and Santoro, L.D., "Waste Oil Combustion: An Environmental Case Study," 75th Annual Meeting of the Air Pollution Control Association, Paper 82-5.1, New Orleans, June 20, 1982.

This paper details a study done by Skidmore College engineers concerning the possibility of burning undiluted waste crankcase oil in the college's boiler system. Required boiler modifications and experimentally determined combustion emissions are described.

Walker, W.B., "Pollution of the Environment by the Burning of Waste Oils," in Recycling of Used Oils, D. Reidel Publishing Co., Dordrecht, Holland, 1980.

This paper examines air pollution caused by space heaters burning three types of waste oils: untreated waste oil, dewatered waste oil, and gas oil. Physical characteristics of the fuels, gas volumes, and particulate emissions are tabulated.

Weeter, D.W., "Utilization of an Industrial Waste Oil as an Alternative Fuel for a Municipal Sludge Incinerator," in Toxic and Hazardous Wastes Proceedings of the Sixteenth Mid-Atlantic Industrial Waste Conference, Ed. by Lagrega, M.D. and Long, D.A., Technomic Publishing Co., Lancaster PA, 1984.

This paper describes the potential use of waste oil as a fuel for cofiring incinerators burning wastewater sludges. Test burns, system design, permit effects, and operations history are discussed.

B.8 Biological Treatment

Atlas, R.M., ed., Petroleum Microbiology, Macmillan Publishing Co., New York, 1984.

Reviews current understanding of the interactions between microorganisms and petroleum products in a variety of environments.

"Biological Treatment of Contaminated Ground Water: Requirements and Options," Hazardous Waste Consultant, Sept./Oct., 1985, p. 1-1.

Reviews biological processes that can be used to destroy the organic material in contaminated aqueous systems.

Bossert, I., and Bartha, R., "Fate of Petroleum in Soil Ecosystems," in Petroleum Microbiology, MacMillan, New York, 1984.

This article describes accidental and deliberate methods of introducing oil to soil systems and the effects of petroleum pollutants on plants and animals. Metabolism and chemical degradation of petroleum are also discussed.

Dibble, J.T., and Bartha, R., "Effects of Environmental Parameters on the Biodegradation of Oil Sludge," App. Envir. Microbiology, Oct., 1979, p. 729.

This article describes laboratory experiments performed to determine optimal environmental conditions for oil sludge biodegradation. Ideal nutrient concentrations are estimated.

Floodgate, G.D., "The Fate of Petroleum in Marine Ecosystems," in Petroleum Microbiology, MacMillan, New York, 1984.

A description is presented of the impacts of oils and oil-based products upon the biological functions of different forms of marine life. Ability of aquatic organisms to metabolize oil and ultimate fate of oils that are introduced to marine environments are discussed.

Forster, C.F., Biotechnology and Wastewater Treatment, Cambridge University Press, Cambridge, 1985.

Biological processes can be used to treat a variety of different waste streams. Topics discussed include water pollution control, industrial effluent treatment, and wastewater treatment in developing countries. Design and operating data are given for biological treatment systems.

Geldner, P., "Stimulated In Situ Biodegradation of Aromatic Hydrocarbons," Second International Conference on New Frontiers for Hazardous Waste Management, Pittsburgh, August, 1987, p. 97.

Describes the clean-up of contaminated soil by stimulating the biodegradation of the organic contaminants.

"Getting the Bugs In," Orange County South, Feb. 1985, p. 36.

This article describes Solmar Corporation's use of bioaugmentation for sludge reduction and treatment of hazardous waste and wastewater.

Golueke, C.G., Biological Reclamation of Solid Wastes, Rodale Press, Emmaus PA, 1977.

Topics discussed in the volume include composting, land disposal of sewage sludge, and anaerobic digestion. Technology, economics, and current practices in the area of biological treatments are described.

Grubbs, R.B., "Biotechnology Proves Good Examples," Pollution Engineering, June 1986.

A description is given of the use of bioaugmentation as a means of increasing the efficiency of biological waste treatment systems. Experiences of bioaugmentation with petroleum based wastes are described.

Grubbs, R.B., Environmental Applications of Biotechnology: The Current State of the Art, Conf. on Genetic Control of Environmental Pollutants, Sponsored by the University of Washington, U.S. Environmental Protection Agency, National Toxicity Program, and Council for Research Planning in Biological Sciences, Seattle, July 31, 1983.

An overview is given as to how biological techniques can be used to treat petroleum-based wastes, hazardous wastes, industrial wastewater, and domestic sewage.

Grubbs, R.B., Reducing Energy Needs Through Biotechnology, presented at the Fifth Annual Convention of the Hawaii Water Pollution Control Association, Jan. 28, 1983.

This paper describes how biotechnology can be used to extend equipment life and save money by treating deposits of waste oil and grease.

Robichaux, T.J., and Myrick, N.H., "Chemical Enhancement of the Biodegradation of Crude Oil Pollutants," Journal of Petroleum Technology, Jan. 1972, p. 16.

This article describes chemical constituents that can be added to soils to increase the rate and efficiency of oil biodegradation. Mechanisms of degradation of oil by microorganisms are described.

Somerville, H.J., "Physiological Aspects of Biotreatment of Petrochemical Wastes," Conservation and Recycling, 6: 1, 73 (1985).

This article describes how aerobic biotreatment can be used to treat petrochemical wastes. Experimental results are given that demonstrate respiration requirements and biomass capacities of aerobic digestion.

Sutton, P.M., Mishra, P.N., and Hachigan, L., "Using Biotechnology to Treat Metalworking Wastewater," Pollution Engineering, April 1986, p.46.

The relative merits of biologically treating synthetic oil-bearing wastewater from metalworking operations are discussed. Pilot plant experimental results are given, and oxygen demand and excess sludge production are estimated.

Westlake, D.W.S., "Heavy Crude Oils and Oil Shales: Tertiary Recovery of Petroleum from Oil-Bearing Formations," in Petroleum Microbiology, Ed. by Atlas, R.M., MacMillan, New York, 1984.

This article considers the involvement of microorganisms, particularly bacteria, in the formation and utilization of heavy crude oils and oil shales with a view towards the potential use of bacteria in the tertiary recovery of petroleum from oil-bearing formations.

B.9 Wastewater Pretreatment

Alexander, W.D., and Maul, P.L., "Evaluation of Treatment System For Spent Machine Coolants and Oily Wastewater," 36th Annual Purdue Industrial Waste Conference, May, 1981.

Describes a method for the treatment of wastewater containing low levels of emulsified, water soluble oils and petrochemicals using a montmorillonite based chemical formulation.

Bennett, G.F., and Philipp, C.T., Industrial Wastewater Pretreatment, Seminar sponsored by University of Toledo Division of Continuing Education, Santa Clara CA, Sep. 16, 1987.

The main topic of this seminar is the impacts of wastewater pretreatment regulations recently promulgated by USEPA upon both municipal sewer systems and industrial wastewater generators. A regulatory review is given, and a discussion is presented of treatment methods for oil recovery, solids removal, sludge handling, and handling of toxic contaminants.

Cheremisinoff, "Update on Wastewater Treatment," Poll. Eng., Sep., 1986, p. 20.

This article presents a summary of current wastewater treatment techniques, including methods of oil-water separation. Choice of a method depends on many factors, including environmental regulations, resource management, and economics.

Ford, D., and Elton, R., "Removal of Oil and Grease from Industrial Wastewaters," Chem. Eng., Oct. 12, 1977.

A review of the treatment technology typically utilized for oil and grease removal, along with examples of treatment efficiency and typical effluent quality, is presented. Brief discussions are included for several processes which, although not in general use, are suggested as potentially applicable for oil and grease removal. A summary table showing advantages and disadvantages of the various processes is included.

Hubbell, G.E., "CPI vs API for Storm Water Treatment," Pollution Engineering, Sep. 1986, p. 58.

This article describes experiences with American Petroleum Institute (API) oil separation facilities and corrugated plate interceptor (CPI) oil separators used on effluent water streams from a large Midwestern automobile transmission plant.

Oblinger, F.G., Weintraub, M., Blais, E.J., and Gealer, R.L., "Automation of an Electrolytic Cell for the Treatment of Oily Wastewater," Env. Prog., 5: 4, 283 (1986).

This article describes use of a control system on a continuous process at an automotive transmission plant in which wastewater passes through a porous iron chip bed anode where oil emulsion is demulsified by electrolytically dissolved iron.

Rhee, C.H., Martyn, P.C., and Kremer, J.G., "Removal of Oil and Grease in the Hydrocarbon Processing Industry," 42nd Purdue Industrial Waste Conference, Purdue IN, 1987.

This paper describes wastewater pollutants generated by the hydrocarbon processing industry and how they are treated. Oil and grease removal technologies are summarized to assist dischargers in complying with their limits.

B.10 Emerging and Innovative Technologies

Austin, D.A., "The B.E.S.T. Process Deoiling/Dewatering of Sludges and Soils," Resource Conservation Co., Seattle, 1987.

A technical description is given of the B.E.S.T. process, which employs inverse miscibility properties of aliphatic amines to break down suspensions and emulsions in sludges and contaminated soils. Potential applications for wastes from refineries and petrochemical plants, and for wastewater treatment are also discussed.

Copa, W., Heimbuch, J., Schaefer, P., "Demonstration of Wet Air Oxidation of Hazardous Waste," Proceedings of 10th Research Symposium, EPA 600/9-84-002, 1984.

This paper summarizes the full scale demonstration of wet air oxidation of hazardous waste. Wet air oxidation is a process which is used to oxidize dissolved or suspended substances at elevated temperatures.

Edwards, B.H., Paullin, J.N., and Coghlan-Jordan, K., Emerging Technologies for the Control of Hazardous Waste, Noyes Data Co., Park Ridge NJ, 1983.

This book reviews and assesses emerging technologies or novel variations of established technologies for the control of hazardous wastes. The three technologies covered in detail are molten salt combustion, fluidized bed incineration, and ultraviolet/ozone destruction.

Freeman, H., Innovative Thermal Hazardous Organic Waste Treatments, Noyes Data Co., Park Ridge NJ, 1985.

This book contains discussions of 21 thermal processes identified by the U.S. EPA as innovative processes for treating or destroying hazardous organic wastes. Both emerging technologies and technologies in commercial operation are included. The information is intended to assist in the evaluation of alternative hazardous waste treatment processes.

Freeman, H., "Update on New Alternative Hazardous Waste Treatment Processes," Performance and Costs of Alternatives to Land Disposal of Hazardous Waste, Air Pollution Control Association, New Orleans, Dec. 8, 1986.

Several innovative hazardous waste treatment techniques are discussed, including the use of supercritical fluids for the oxidation of waste oils and organic wastes.

Lawson, M., "New Technology Tackles Dilute Wastes," Chemical Week, Oct. 1, 1986, p. 40.

A discussion is presented of the technology and potential applications of the MODAR supercritical water oxidation process.

McGrew, J.L., Hartman, G.L., Cassetti, C.B., Barnes, G.E., and Eralp, A., "Wet Oxidation of Municipal Sludge by the Vertical Tube Reactor," Project Summary, EPA/600/S2-86/043, June 1986.

Describes the experimental evaluation of a vertical-tube reactor system for treating municipal wastewater sludges. The system is designed to oxidize high-strength liquid organic wastes using wet combustion principles.

Modell, M., "Supercritical Fluid Technology in Hazardous Waste Treatment," Presented at the International Congress on Recent Advances in the Management of Hazardous and Toxic Wastes in the Process Industries. Vienna, Austria, March 8-12, 1987.

This paper describes theory and applications of supercritical fluid technology in the physical and chemical treatment of hazardous and toxic wastes. The two applications discussed are oxidation of organics in supercritical water and extraction of organics with supercritical carbon dioxide.

Modell, M., and Thomason, T.B., Supercritical Water Destruction of Dilute Aqueous Wastes, Presented at the Second International Symposium on Operating European Centralized Hazardous Waste Management Facilities, Odense, Denmark, September, 1984.

This paper summarizes theory and design aspects of the supercritical water oxidation process. Process requirements are listed and destruction efficiencies are estimated.

Norheim, C.M., Allen, C.C., and Harkins, S.M., Pilot Scale Evaluation of a Thin-Film Evaporator for Volatile Organic Removal from Land Treatment Sludges. Report by Research Triangle Institute, Research Triangle Park NC, 1987.

This report describes a study done of thin-film evaporators and their use in removing and recovering volatile organics from refinery wastes and waste petroleum sludges prior to land treatment, thus reducing the amount of volatiles available for release to the atmosphere.

"Solvent Extraction Technology Used on Oily Sludges at Superfund Site," Haztech News, Nov. 20, 1986, p. 163.

This article describes how the Basic Extraction Sludge Treatment (B.E.S.T.) process is being used to treat oily sludges and filter cake at a refinery Superfund site.

Staszak, C.N., Malinowski, K.C., and Killilea, W.R., "The Pilot-Scale Demonstration of the MODAR Oxidation Process for the Destruction of Hazardous Organic Waste Materials," Environmental Progress, 6: 1, 39, 1987.

This article describes field tests in which two organic waste streams were destroyed using the MODAR process. The MODAR process utilizes water at conditions above its critical point as the reaction medium for oxidation of organic materials.

Staszak, C.N., Malinowski, K.C., Killilea, W.R. and Swallow, K.C., "The Destruction of Hazardous Organic Waste Materials Using the MODAR Oxidation Process," Second International Conference on New Frontiers for Hazardous Waste Management, Pittsburgh, August, 1987, p. 97.

This article describes field tests in which two organic waste streams were destroyed using the MODAR process. The MODAR process utilizes water at conditions above its critical point as the reaction medium for oxidation of organic materials (Same as above).

"Supercritical Water Oxidation," Hazardous Waste Consultant, May/June 1986, p.4-21.

A discussion is given of the technology, economics, and potential applications of the supercritical water oxidation process offered by MODAR Inc.

"Vertech Wet Oxidation Process," Hazardous Waste Consultant, May/June 1986, p.4-23.

This article describes the technology, economics, and potential applications of the Vertech wet oxidation process. This process utilizes deep well injection to produce supercritical conditions, under which organic wastes are efficiently oxidized.

"Zimpro Wet Oxidation Process," Hazardous Waste Consultant, May/June 1986, p.4-25.

A discussion is given of the technology and potential applications of the Zimpro Inc. wet oxidation process. This process involves the thermal oxidation of aqueous organic wastes.

B.11 Land Disposal and Cleanup

Higgins, T.E., Dunckel, J.R., and Marshall, B.R., "Treatment Alternatives to Land Disposal of Hazardous Waste," in Performance and Costs of Alternatives to Land Disposal of Hazardous Waste, Transactions of APCA International Specialty Conference, New Orleans, Dec., 1986.

This report describes past experiences in using land disposal for hazardous waste treatment, and describes emerging technologies and case histories concerning land disposal phase out.

Mittelhauser Corp., Evaluation of Alternative Technologies to Land Disposal for Oil Industry Wastes, Western Oil and Gas Association, 1987.

This report presents the results of a study to evaluate selected technologies with potential to reduce the volume and toxicity of hazardous wastes generated by the oil industry.

Parr, J.F., Marsh, P.B., and Kla, J.M., Land Treatment of Hazardous Wastes, Noyes Data Co., Park Ridge NJ, 1983.

Processes that influence the fate of wastes in soil are described. Results from land treatment of specific wastes are presented. Included is a discussion of degradation of petroleum products by microorganisms.

Performance and Costs of Alternatives to Land Disposal of Hazardous Waste," ed. by Oppelt, E.T., Blaney, B.L., and Kemner, W.F., Air Pollution Control Association, New Orleans, Dec. 8, 1986.

This conference was designed to focus on the performance and cost information that hazardous waste handlers need to respond to the Hazardous and Solid Waste Act of 1984. Topics covered include conventional alternatives, emerging technology, industrial case studies, and comparative assessments of processes.

Stokman, S.K., Dime, R., "Soil Cleanup Criteria for Selected Petroleum Products," Proceedings of the National Conference on Hazardous Wastes and Hazardous Materials, Hazardous Materials Control Research Institute, Silver Spring MD, 1986.

This paper compares alternatives for developing cleanup objectives for soil contaminated with petroleum products. Comparison of a soil cleanup objective based on the concentrations of total petroleum hydrocarbons versus a soil cleanup objective based on the concentration of individual chemical constituents of concern is investigated.

B.12 Economic and Environmental Impacts

Brinkman, D.W., Whisman, M.L., and Emmerson, H.R., Environmental, Resource Conservation, and Economic Aspects of Used Oil Recycling, DOE/BETC/RI-80/11, April, 1981.

This study compares burning used oils with rerefining from economic, environmental, and energy conservation view points. Four scenarios are used with conditions ranging from unrestricted burning of used oils without government constraints to the complete prohibition of burning thereby funneling all used oil to rerefining.

"Dealer Survival in the Lube Oil Business," Lundberg Letter, Vol. XIII, No. 26, April 25, 1985.

This paper discusses the competition and the competitors in the oil-change and lube service business. The relationship of lube oil prices to crude oil prices is discussed. Techniques for bringing the do-it-yourself oil changer into the used management system are examined.

"DOE Report Assesses Environmental Impact of Waste Oil Industry," JAPCA, 37: 7, 780 (1987).

This article discusses how recent regulatory action taken in the U.S. may force used oil handlers out of the market and decrease the availability of sound used oil disposal options.

Jones, S.T., "Forecasting Oil Prices to 1995," Hydrocarbon Processing, August, 1987, p. 78-A.

The author presents two oil price scenarios that represent high and low attainable price trends, and estimates the impact of each trend on worldwide oil usage.

Metzler, S.C., and Jarvis, C., "Effects of Waste Oil Contamination," Env. Prog., 4: 1, 61 (1985).

The objective of this report is to evaluate the potential for harm to human health or to the environment presented by the use of waste oil as a dust suppressant. Environmental fates of waste oil components are examined.

Serne, J.C., and Wilson, K., The Use and Fate of Lubricants, Oils, Greases, and Hydraulic Fluids in the Iron and Steel Industry, EPA/600-2-78-101, May, 1978.

Lubrication needs and practices of the iron and steel industry are presented. Waste oil collection and reclamation methods are discussed. Of all lubricants used, an estimated 10 percent enter the environment as air pollution, 9 percent as water pollution, and 44 percent as solid waste.

Surprenant, N.F., Battye, W.H., and Fennelly, P.F., The Fate of Hazardous and Nonhazardous Wastes in-Used Oil Disposal and Recycling. Dept. of Energy Report No. DOE/BC/10375-6. Bartlesville OK, October, 1983.

The primary objective of this report is to identify the hazardous and nonhazardous compounds that might be found in used oil and to establish their fate under a variety of disposal and recycling scenarios. Management options considered are sewer disposal, road oiling, combustion as fuel, physical reprocessing to produce specification fuel, and various rerefining processes. A secondary objective is to assess environmental impacts of contaminants in the waste and product streams.

A Technical and Economic Study of Waste Oil Recovery. Parts I-VI, Teknekron Inc. Report for EPA, NTIS PB-237 618,619,620, PB-251 716, October 1973.

Subjects covered in this six-part study include federal research on waste oil from automobiles, an investigation of dispersed sources of used crankcase oils, economic and technical barriers to waste oil recovery, energy consumption in waste oil recovery, a test of rerefined lube oil quality, and a review of rerefining economics.

Waste Oil Study. Report to Congress, EPA Report, NTIS PB-257 693/2BE, PC A18/MF A01, April 1974.

This report presents the results of studies undertaken to determine the extent of problems resulting from disposal of waste oils and the effects of disposal techniques on the environment.

B.13 Management in Other States and Countries

Gabris, T., Emulsified Industrial Oils Recycling, Dept. of Energy Report No. DOE/BC/10183-1, Bartlesville OK, April 1982.

The industrial lubrication market is analyzed with emphasis on current and/or developing recycling and rerefining technologies in the U.S. and other industrial countries. Specific topics covered include used oil market analysis, regulatory developments, disposal and reclamation practices and costs, and recycling practices.

Siemon, D.M., Agnew, J.B., and Salusinszky, A.L., "Recycling of Used Lubricating Oils in Australia," Conservation and Recycling, Vol. 3, 1979, p. 25.

Satisfactory rerefining of waste oil in Australia has become increasingly difficult to achieve; the reasons for this are examined. Several alternative reprocessing steps are investigated. Major changes in reprocessing technology are required to provide incentives to rerefine used oil.

B.14 Bibliographies and Databases

Brinkman, D.W., Cotton, F.O., and Olsen, M., Recovery of Naval Distillate Fuel from Reclaimed Product Volume 2: Literature Review, Nat. Inst. for Petroleum and Energy Research Report No. B06508-3, Bartlesville OK, June, 1984.

This volume is a review of recent literature concerned with waste hydrocarbons. It contains 781 annotated references. Among subjects included are oil/water separation, recovery of oil from sludge, and treatment processes.

Cotton, F.O., Waste Lubricating Oil: An Annotated Review, DOE/BETC/IC-82/4, Bartlesville OK, Oct., 1982.

This volume is a review of recent literature concerned with production, analysis, collection, regulation, and treatment of waste lubricating oil. It contains 1203 annotated references.

Hazardous Waste Information System, CA Dept. of Health Services Program ID: HWM932H, Sacramento, Feb. 13, 1987.

This system is a computerized database containing current technological information concerning hazardous waste management. Categories in the database include waste oil, sludge oil/water separation, and oil-containing waste.

Hunt G., and Schecter, R., Pollution Prevention Bibliography, Pollution Prevention Pays Program, North Carolina Dept. of Natural Resources and Community Development, Raleigh. March, 1987.

This volume is a bibliography containing references concerned with regulating, reducing and treating pollution sources. One section containing 17 references is devoted to petroleum-based products.

Waste Oil Reclamation (Jan. 70- Aug 86) Citations from the NTIS Bibliographic Database, NTIS PB86-873890, 1986.

This volume contains references and abstracts for all articles concerning waste oil reclamation that are contained in the NTIS database. Approximately 140 references are listed.

Lehmann, E.J., Oil Water Separators (Citations from the American Petroleum Institute Database), NTIS PB80-801954, Dec. 1979.

This volume lists references from the API Database on the subject of physical methods of oil/water separation. Subjects discussed include absorbers, ballast, coalescers, filters, and decontaminators.

APPENDIX C
ORDER FORM FOR CALIFORNIA HAZARDOUS
WASTE CONTROL LAWS AND REGULATIONS

ORDER FORM FOR CALIFORNIA HAZARDOUS WASTE CONTROL
LAWS AND REGULATIONS

Copies of hazardous waste control laws and regulations administered by the California Department of Health Services may be ordered by completing the form below and mailing it with the applicable payment to:

Department of General Services, Publications Section
P.O. Box 1015
North Highlands, CA 95660

The laws and regulations are *not* identical, so both are generally needed to obtain complete information.

The laws (Chapters 6.5 through 6.98, Division 20, California Health and Safety Code) were enacted by the Legislature. Recent history indicates that the laws change to some extent each year, usually effective January first. To keep up to date with the laws, reorder them each year, because no amendment service is available.

The regulations (Chapter 30, Division 4, Title 22, California Administrative Code) were adopted by the Department of Health Services within the scope of the DHS' authority under the laws. The regulations may change at any time during the year according to specified administrative procedures. Therefore, continuous amendment service is available by subscription. The amendment service is useful only in conjunction with the complete regulations (i.e., Division 4, Title 22, CAC).

I. Please check all applicable boxes and complete all applicable blanks.

- ☐ Please send me _____ copy(ies) of *Item No. 7540-958-1016-6, Hazardous Waste Control Law* (Chapters 6.5 – 6.98, Division 20, Health and Safety Code), at \$13.35 per copy, including postage, taxes, and handling costs. S _____
- ☐ Please send me _____ copy(ies) of the regulations (Division 4, Title 22, California Administrative Code (CAC)) at \$8.48 per copy, including postage, taxes, and handling costs. S _____
- ☐ Please accept my _____ subscription(s) to the continuous amendment service for the regulations (Division 4, Title 22, CAC) at \$12.00 per subscription per year, including postage and handling costs. The complete regulations must be ordered separately by checking the applicable box. S _____

Make check or money order for the total amount payable to: State of California.

TOTAL AMOUNT S _____

II. Please print or type your mailing address and telephone number below; then sign and date the form.

Name/Company Name _____

Attention _____

Address _____

City _____ State _____ Zip _____

Telephone Number _____ (In case we need to contact you about your order)

Signature _____

Date _____

APPENDIX D
ARTICLE 13. MANAGEMENT OF USED OIL

Article 13. Management of Used Oil
(Added by Stats. 1986, Ch. 871)

25250. (a) The Legislature finds that almost 100 million gallons of used oil is generated each year in the state; that this oil is a valuable petroleum resource which can be recycled; and that, in spite of this potential for recycling, significant quantities of used oil are wastefully disposed of or improperly used by means which pollute the water, land, and air, and endanger the public health, safety, and welfare.

(b) The Legislature also finds that readily available technologies exist to recycle used oil into useful products and that used oil should be collected and recycled, to the maximum extent possible, by means which are economically feasible and environmentally sound, in order to conserve irreplaceable petroleum resources, to protect the environment, and to protect public health, safety, and welfare.

(Added by Stats. 1986, Ch. 871.)

25250.1. As used in this article, the following terms have the following meanings:

(a) "Used oil" means any of the following:

(1) Any oil that has been refined from crude oil, and has been used, and, as a result of use, has been contaminated with physical or chemical impurities.

(2) Any oil that has been refined from crude oil and, as a consequence of extended storage, spillage, or contamination with nonhazardous impurities such as dirt and water, is no longer useful to the original purchaser.

(3) Spent lubricating fluids which have been removed from an engine crankcase, transmission, gearbox, or differential of an automobile, bus, truck, vessel, plane, heavy equipment, or machinery powered by an internal combustion engine.

(4) Spent industrial oils, including compressor, turbine, and bearing oil, hydraulic oil, metal-working oil, refrigeration oil, and railroad drainings.

(5) Contaminated fuel oil with a flash point greater than 100°F. "Used oil" does not include oil which has a flash point below 100°F or which has been intentionally mixed with hazardous waste, other than minimal amounts of vehicle fuel. "Used oil" also does not include oil which contains polychlorinated biphenyls (PCBs) at a concentration of 5 ppm or greater.

(b) "Board" means the California Waste Management Board.

(c) "Recycled oil" means any oil, produced from used oil, which has been prepared for reuse and which achieves minimum standards of purity, in liquid form, as established by the department. The following standards of purity are in effect unless the department, by regulation establishes more stringent standards:

(1) Flash point: minimum standards set by the American Society for Testing and Materials for the recycled products.

(2) Lead: 100 ppm or less prior to January 1, 1988; 50 ppm or less on and after January 1, 1988.

(3) Arsenic: 5 ppm or less.

(4) Chromium: 10 ppm or less.

(5) Cadmium: 2 ppm or less.

(6) Chlorides: 3,000 ppm or less.

(7) Polychlorinated byphenyls (PCBs): 5 ppm or less.

Compliance with these standards shall be determined in accordance with the procedures in Article 11 (commencing with Section 66693) of Chapter 30 of Division 4 of Title 22 of the California Administrative Code.

(d) The standards set in subdivision (c) include the only concentrations allowed above the criteria adopted pursuant to Section 25141.

(e) Used oil which meets the standards set in subdivision (c) and the criteria adopted pursuant to Section 25141 for constituents other than those listed in subdivision (c) is not regulated by the department. Any person who generates used oil and who claims that the oil meets those standards and criteria, shall notify the department of its claim and shall comply with the testing and recordkeeping requirements of Section 25250.19 prior to its reuse. In any action to enforce this article, the burden is on the generator and user of the used oil to prove that the oil met those standards and criteria.

(Added by Stats. 1986, Ch. 871.)

25250.3. Any virgin oil product or partially refined product, which has not been previously used, which has become contaminated with non-hazardous impurities such as dirt or water, and which has been returned to bulk storage by the product's manufacturer, transporter, or wholesaler for gravity separation of contaminants, is exempt from this article. Any petroleum product which becomes contaminated with any other petroleum product during refining, transportation by pipeline, or storage and which remains usable as a refinery feed stock or as a refinery fuel is exempt from this article.

(Added by Stats. 1986, Ch. 871.)

25250.4. Used oil regulated by the department shall be managed as a hazardous waste in accordance with the requirements of this chapter until it has been recycled. Used oil which is not recycled shall be disposed of, or transported out of the state, as a hazardous waste in accordance with this chapter.

(Added by Stats. 1986, Ch. 871.)

25250.5. (a) Disposal of used oil by discharge to sewers, drainage systems, surface or groundwaters, watercourses, or marine waters; by incineration or burning as fuel; or by deposit on land, is prohibited, unless authorized under other provisions of law.

(b) The use of used oil as a dust suppressant or weed control agent is prohibited.

(Added by Stats. 1986, Ch. 871.)

25250.7. No person who generates, receives, stores, transfers, transports, treats, or recycles used oil shall intentionally contaminate used oil or knowingly accept used oil which has been contaminated with other hazardous waste, other than minimal amounts of vehicle fuel.

(Added by Stats. 1986, Ch. 871.)

25250.8. Used oil shall be manifested under either one of the following procedures:

(a) The procedures prescribed by Sections 25160 and 25161.

(b) The following modified manifesting procedure, which may be used only by a registered hazardous waste hauler and shall be used only with the consent of the generator:

(1) A separate manifest shall be completed by each vehicle driver, with respect to each transport vehicle operated by that driver for each date.

(2) An Environmental Protection Agency identification number is not required for an individual generator.

(3) The hauler shall complete both the generator's and the hauler's sections of the manifest using the hauler's name. The hauler's section shall be completed prior to commencing each day's used oil collections. The driver shall sign and date the generator's and hauler's sections of the manifest.

(4) The hauler's name, Environmental Protection Agency identification number, and terminal address shall be entered in the generator's name, address, and Environmental Protection Agency identification number spaces of the manifest.

(5) The hauler shall attach to the front of the manifest legible receipts for each quantity of used oil that is received from a generator. The receipts shall be used to determine the total volume of used oil in the vehicle. After the used oil is delivered, the receipts shall be affixed to the hauler's copy of the manifest. The hauler shall leave a copy of the receipt with the generator of the used oil. The generator shall retain each receipt for at least three years.

(6) All copies of each receipt shall contain all of the following information:

(A) The name, address, and telephone number of the generator, and the signature of the generator or the generator's representative.

(B) The date of the shipment.

(C) The state manifest number.

(D) The volume of the used oil received and its proper shipping description, including the hazardous class and identification number, if applicable.

(E) The address of the permitted facility to which the used oil will be transported.

(F) The hauler's name, address, and Environmental Protection Agency identification number.

(G) The driver's signature.

(7) The hauler shall enter the total volume of used oil transported on the manifest at the change of each date, change of driver, change of transport vehicle, or upon the last delivery of used oil to the designated facility. The total volume shall be the cumulative amount of used oil collected from the generators listed on the individual receipts.

(8) The hauler shall submit the generator copy of the manifest to the department within 30 days of each shipment.

(9) The hauler shall retain a copy of the manifest and all receipts for each manifest for three years.

(10) The hauler shall submit all copies of the manifest to the designated facility. A representative of the designated facility which receives the used oil shall sign and date the manifest, return two copies to the hauler, retain one copy, and send the original to the department within 30 days.

(11) All other manifesting requirements of Sections 25160 and 25161 shall be complied with unless specifically exempted under this subdivision.

(Added by Stats. 1986, Ch. 871.)

25250.10. Every registered hazardous waste hauler who transports used oil shall report to the department the following information as part of the hauler's annual application for renewal of registration:

(a) The shipping descriptions of used oil transported during the preceding year.

(b) The volume of each type of used oil transported, identified by shipping description.

(c) The facilities to which the used oil was transported, identified by name, address, telephone number, and Environmental Protection Agency identification number.

(Added by Stats. 1986, Ch. 871.)

25250.11. (a) Any person who receives used oil from consumers or other used oil generators, is exempt from hazardous waste facility permit requirements imposed pursuant to Article 9 (commencing with Section 25200) of this chapter with respect to any location at which used oil is received if all of the following conditions are met:

(1) Each shipment of used oil received does not exceed 20 gallons, and the contents of any single container does not exceed five gallons.

(2) No other hazardous wastes are received at the location.

(3) The used oil is transported by the generator of the used oil.

(b) Any person who transports used oil to a location that is exempt from Article 9 (commencing with Section 25200) pursuant to subdivision (a) is exempt from the requirements of subdivisions (a) and (e) of Section 25163 and from the requirements of Section 25160 concerning the possession of a manifest while transporting used oil if all of the following conditions are met:

- (1) The contents of any single container do not exceed five gallons.
 - (2) Each shipment of used oil does not exceed 20 gallons.
 - (3) The person transporting the used oil had used the oil.
- (Added by Stats. 1986, Ch. 871.)

25250.15. Any person operating a refuse removal vehicle or a curbside collection vehicle used to collect or transport used oil which has been generated as a household waste or as part of a curbside recycling program, as defined by the board, is exempt from the requirements of Section 25160 and subdivisions (a) and (e) of Section 25163 of this code and Chapter 2.5 (commencing with Section 2500) of Division 2, Division 14.1 (commencing with Section 32000), and subdivision (g) of Section 34500 of the Vehicle Code.

(Added by Stats. 1986, Ch. 871.)

25250.16. No person may recycle used oil without obtaining a permit from the department.

(Added by Stats. 1986, Ch. 871.)

25250.17. Each used oil recycler who has been issued a permit by the department shall submit a report, on or before March 1 of each year, to the department containing all of the following information:

(a) The total volume of used oil possessed at the beginning and end of the preceding calendar year.

(b) The total volume of used oil received during the preceding calendar year.

(c) The total volume of used oil recycled during the preceding calendar year, itemized as follows:

(1) Prepared for reuse as a petroleum product

(2) Consumed in the process of preparing for reuse, including wastes generated.

(3) Prepared for reuse other than as a petroleum product, specifying each type of other use.

(4) Not recycled but transported offsite.

(d) Any other information which the department may require.

(Added by Stats. 1986, Ch. 871.)

25250.18. Any person who transports recycled oil shall maintain with each shipment of recycled oil the shipment's destination and a signed and dated form from the recycling facility certifying that the oil being transported has been tested and is in compliance with the standards specified in subdivision (c) of Section 25250.1.

(Added by Stats. 1986, Ch. 871.)

25250.19. A registered used oil recycler shall ensure that all recycled oil transported from the recycling facility has been tested and certified as being in compliance with the standards specified by subdivision (c) of Section 25250.1. Records of tests performed and a copy of each form completed pursuant to Section 25250.18 shall be maintained for three years and are subject to audit and verification by the department or the board.

(Added by Stats. 1986, Ch. 871.)

25250.20. Any person whose permit or registration has been revoked may not apply for a new or renewed permit or registration for a period of one year after the revocation of the permit or registration.

(Added by Stats. 1986, Ch. 871.)

25250.21. Any person whose permit or registration has been revoked may not serve in the employ of a hazardous waste hauler or used oil recycler during the period of revocation of the permit or registration.

(Added by Stats. 1986, Ch. 871.)

25250.22. All rules and regulations of the department shall be adopted, amended, and repealed in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code.

(Added by Stats. 1986, Ch. 871.)

25250.23. Any person who transports used oil shall register as a hazardous waste hauler and, unless specifically exempted or unless the used oil is not regulated by the department pursuant to subdivision (e) of Section 25250.1, shall comply with all provisions of this chapter.

(Added by Stats. 1986, Ch. 871.)

25250.24. Any person who generates, receives, stores, transfers, transports, treats, or recycles used oil, unless specifically exempted or unless the used oil is not regulated by the department pursuant to subdivision (e) of Section 25250.1, shall comply with all provisions of this chapter.

(Added by Stats. 1986, Ch. 871.)

APPENDIX E
RECYCLABLE MATERIAL

25143.2. (a) A recyclable material is subject to the requirements of this chapter which apply to hazardous waste unless the department waives the provision of this chapter pursuant to Section 25143, or except as provided otherwise in subdivision (b) or the regulations adopted by the department pursuant to Sections 25150 and 25151.

(b) Except as otherwise provided in subdivision (c), recyclable material is exempt from regulation under this chapter if the material meets any of the following conditions:

(1) Is recycled and used at the site where the material was generated.

(2) Has been handled by a facility authorized by the department pursuant to Article 9 (commencing with Section 25200) if the material resulting from the facility's handling process meets both of the following requirements:

(A) Contains no hazardous constituents, other than those for which the material is being recycled.

(B) Is used, or distributed or sold for use, in a manner for which that material is commonly used.

(3) No longer conforms to a criterion adopted by the department pursuant to Section 25141.

(4) Is transferred between two or more facilities operated by the same person, if the material is being transferred for purposes of recycling.

(5) Is both transported and used, or reused, as an ingredient in an industrial process to make a product, provided the material is not being treated before that use or reuse.

(6) Is both transported and used, or reused, as a safe and effective substitute for a commercial product.

(7) Is returned to the original process from which it was generated, without first being treated. The material shall be returned as a substitute for raw material feedstock, and the process shall use raw materials as principal feedstocks.

(8) Is a petroleum refinery waste containing oil which is converted into petroleum coke at the same facility at which the waste was generated, unless the resulting coke product would be identified as a hazardous waste under this chapter or Public Law 94-580, as amended (the Resource Conservation and Recovery Act of 1976, 42 U.S.C. Sec. 6901 et seq.). This waste is exempt under this chapter to the same extent that this waste is exempt under subsections (q), (r), and (s) of Section 6924 of Title 42 of the United States Code.

(9) Is an oily waste, used oil, or spent nonhalogenated solvent which is managed by the owner or operator of a refinery which is processing primarily crude oil and which is not subject to permit requirements for recycling of used oil, or a public utility, or a corporate subsidiary, corporate parent, or subsidiary of the same corporate parent of the refinery or public utility, and which meets all of the following requirements:

(A) The material is either burned in an industrial boiler, an industrial furnace, an incinerator, or a utility boiler which complies with all applicable federal and state laws, or is recombined with normal process streams to produce a fuel.

(3) The material is either of the following:

(i) Managed at the site where it was generated.

(ii) Managed at another site owned or operated by the generator, a corporate subsidiary of the generator, a subsidiary of the same entity of which the generator is a subsidiary, or the corporate parent of the generator.

(C) The material contains no hazardous constituents other than those for which the material is being recycled.

(c) Notwithstanding subdivision (b), all of the following recyclable materials are subject to the requirements of this chapter which apply to hazardous waste.

(1) Any material used in a manner constituting disposal of the material, or any material used to produce a product that is applied to the land as a fertilizer, soil amendment, agricultural mineral, or an auxiliary soil and plant substance.

(2) Any material burned for energy recovery, used to produce a fuel, or is contained in a fuel, except a material exempted under paragraph (9) of subdivision (b).

(3) Any material accumulated speculatively.

(4) Any materials that have been determined by the Environmental Protection Agency to be inherently waste-like pursuant to Subtitle C of Public Law 94-580, as amended (the Resource Conservation and Recovery Act of 1976, 42 U.S.C. Sec. 6901 et seq.).

(5) Used or spent etchants, stripping solutions, and plating solutions, which are transported to an offsite facility operated by a person other than the generator and which conform to either of the following:

(A) Meet a characteristic or a criterion of a hazardous waste established by the Environmental Protection Agency or the department.

(B) Are listed by the Environmental Protection Agency or the department as a hazardous waste.

(6) Any materials which, if it is to be recycled, is regulated by the Environmental Protection Agency pursuant to Subtitle C of Public Law 94-580, as amended (the Resource Conservation and Recovery Act of 1976, 42 U.S.C. Sec. 6901 et seq.).

(d) This section does not limit, abridge, or supersede any authority granted to the department pursuant to Section 25143.

(e) If the department brings an action to enforce this chapter, any person subject to the action who claims that a certain recyclable material is excluded, exempt, or conditionally exempt, from regulation under this chapter, shall demonstrate that there is a known market or disposition for the material, and that the material meets the requirements of any exemption, exclusion, or conditional exemption from this chapter, by providing appropriate documentation to demonstrate that the material is excluded, exempt, or conditionally exempt, from regulation. Any person subject to such an enforcement action and making such a claim who is a generator of hazardous waste shall provide to the department, upon request, the name, street and mailing address, and telephone number of the owner or operator of the facility that uses or reuses the generator's hazardous waste and a copy of the contract showing that the facility owner or operator uses or reuses that waste as an ingredient in a production process without prior treatment of the waste. Any owner or operator of a facility subject to an action to enforce this chapter who claims to be recycling materials shall show that the facility has the necessary equipment to recycle the material.

(Added by Stats. 1985, Ch. 1594.)

APPENDIX F
KEY TELEPHONE NUMBERS FOR INFORMATION ABOUT
HAZARDOUS WASTES AND HAZARDOUS MATERIALS

California

Department of Health Services/Toxics Program

Used Oil Recycling and Regulatory Information	(916) 324-1807
Manifest and EPA Identification	
Number Information	(916) 324-1781
Recycling of Hazardous Wastes	(916) 324-1807
Northern California Section	(916) 739-3145
North Coast California Section	(415) 540-2043
Southern California Section	(213) 620-2380
Fresno District Office	(209) 445-5938
Transportation Unit	(916) 323-6042
Office of Emergency Services	
24-hour number for reporting spills/releases	(800) 852-7550
Hazardous Materials/Emergency Response Planning	(916) 427-4287
California State Water Resources Control Board	
Water Quality Division	(916) 445-9552
Underground Tank Program	(916) 324-1262
California Waste Management Board	
General Information on Solid Waste	(916) 322-3330
Used-Oil Recycling Center Locations	(800) 553-2962
California Highway Patrol	
Motor Carrier Section	(916) 445-6211

Federal

Environmental Protection Agency (EPA)	
RCRA/Superfund Hotline	(800) 424-9346
Small Business Ombudsman Hotline	(800) 368-5888
Region IX - San Francisco	
General Information	(415) 974-8071
Industry Assistance Line	(415) 974-7472
Emergency Response Section	(415) 974-8131
Asbestos Information	(415) 974-7551
Radon Information	(415) 974-8378
Department of Transportation (DOT)	
Information Hotline	(202) 366-4488
Southern California (El Monte)	(818) 405-7110
Northern California (Sacramento)	(916) 551-1300
U.S. Coast Guard/DOT National Response Center	(800) 424-8802
U.S. Public Health Service, National Health	
Information Clearinghouse	(800) 336-4797

Other:

Chemical Manufacturers Association	
CHEMTREC (transportation accidents)	(800) 424-9300
National Pesticide Telecom Network	(800) 858-7373
National Animal Poison Control Center	(217) 333-3611

APPENDIX G
GENERAL INFORMATION SOURCES

<u>AGENCY</u>	<u>PHONE</u>
1. U.S. EPA RCRA Hotline.....	800-424-9346 or 800-231-3075
2. Toxics Division, Regional Offices	
Berkeley.....	415-540-2043
Los Angeles.....	213-620-2380
Sacramento.....	916-739-3145
Fresno Field Office.....	209-445-5938
3. Regional Water Quality Control Boards	
Los Angeles Region.....	213-620-4460
Oakland Region.....	415-464-1255
Palm Desert Region.....	619-346-7491
Sacramento Region.....	916-361-5600
San Diego Region.....	619-265-5114
San Luis Obispo Region.....	805-549-3147
Santa Ana Region.....	714-782-4130
Santa Rosa Region.....	707-576-2220
South Lake Tahoe Region.....	916-544-3481
4. Air Quality Management Districts	
Bay Area Air Quality Management District.....	415-771-6000
South Coast Air Quality Management District.....	818-572-6212 or 818-572-6153
5. Office of Permit Assistance.....	916-322-4245

LOCAL AIR POLLUTION CONTROL DISTRICTS IN CALIFORNIA

Amador County APCD (Mountain Counties)
Bay Area AQMD (San Francisco Bay Area)
Butte County APCD (Sacramento Valley)
Calaveras County APCD (Mountain Counties)
Colusa County APCD (Sacramento Valley)
El Dorado County APCD (Lake Tahoe and Mountain Counties)
Fresno County APCD (San Joaquin Valley)
Glenn County APCD (Sacramento Valley)
Great Basin Unified APCD (Great Basin Valleys)
Imperial County APCD (Southeast Desert)
Kern County APCD (San Joaquin Valley and Southeast Desert)
Kings County APCD (San Joaquin Valley)
Lake County AQMD (Lake County)
Lassen County APCD (Northeast Plateau)
Madera County APCD (San Joaquin Valley)
Mariposa County APCD (Mountain Counties)
Mendocino County APCD (North Coast)
Merced County APCD (San Joaquin Valley)
Modoc County APCD (Northeast Plateau)
Monterey Bay Unified APCD (North Central Coast)
Mountain Counties Air Basin
North Coast Unified AQMD (North Coast Air Basin)
Northern Sierra AQMD (Mountain Counties Air Basin)
Northern Sonoma County APCD (North Coast)
Placer County APCD (Lake Tahoe, Mountain Counties, and Sacramento Valley)
Sacramento County APCD (Sacramento Valley)
San Bernardino County APCD (Southeast Desert)
San Diego County APCD (San Diego)
San Joaquin County APCD (San Joaquin Valley)
San Luis Obispo County APCD (South Central Coast)
Santa Barbara County APCD (South Central Coast)
Shasta County APCD (Northeast Plateau and Sacramento Valley)
Siskiyou County APCD (Northeast Plateau)
South Coast AQMD (South Coast)
Stanislaus County APCD (San Joaquin Valley)
Sutter County APCD (San Joaquin Valley)
Tehama County APCD (Sacramento Valley)
Tulare County APCD (San Joaquin Valley)
Tuolumne County APCD (Mountain Counties)
Ventura County APCD (South Central Coast)
Yolo-Solano APCD (Sacramento Valley)
Yuba County APCD (Sacramento Valley)